Federal Highway Administration
Long-Term Bridge Performance Program

Briefing on the LTBP Program for NEBPP

John M. Hooks
J. M. Hooks & Associates

Long-Term
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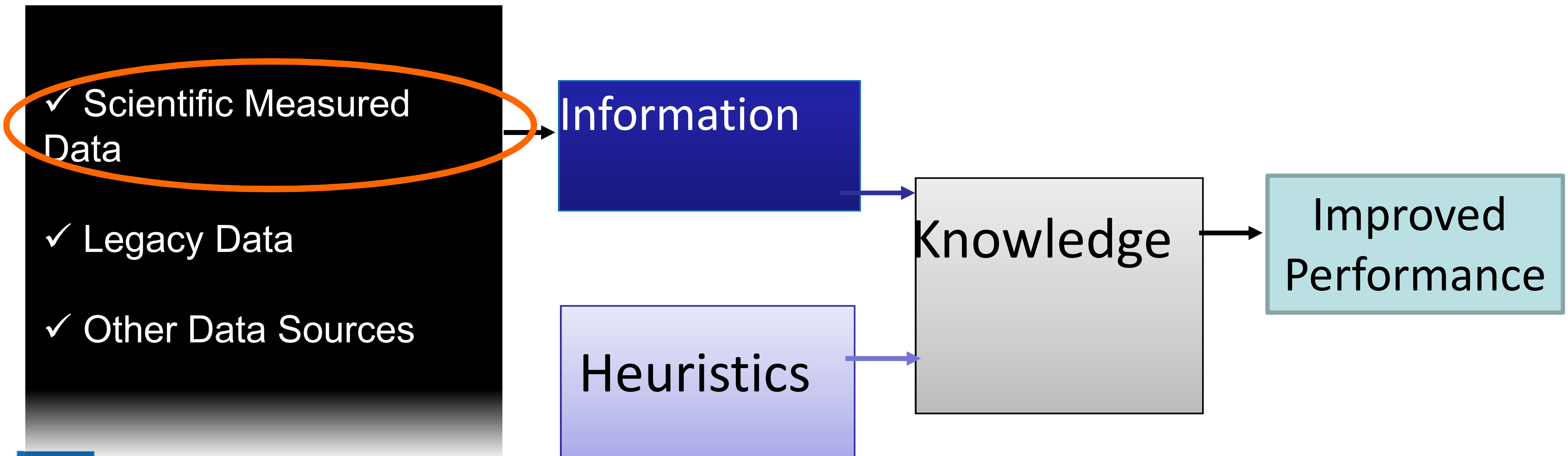
LTBP Program - Quality Information

LTBP – A 20-year research program to collect & synthesize new and existing data to create new knowledge and tools for improving bridge performance



Long-Term Bridge Performance Program

Objective

- Collect, Document, and Maintain a High-Quality Bridge Database
  - Detailed Inspection and Periodic Evaluation
  - Continuous Monitoring
  - Forensic Autopsies

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LTBP – Key Features, Activities & Products

- **LTBP Roadmap**
- **Definition of Bridge Performance**
- **Identification of High Priority Performance Issues**
- **Data Infrastructure – The *Bridge Portal***
- **Protocols for Data Sampling and Collection, and Quality Assurance**

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Task 1.1 - Road Map

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LTBP Study Topics

Category	Issue	Rating	Rank
Decks	Performance of Untreated Concrete Bridge Decks	5.6	1
Decks	Performance of Bridge Deck Treatments	5.6	2
Joints	Performance, Maintenance and Repair of Bridge Deck Joints	5.3	3
Steel Bridges	Performance of Coatings for Steel Superstructure Elements	4.5	4
Concrete Bridges	Performance of Bare/Coated Concrete Super- and Sub-structures	4.5	5
New Bridges	Performance of Innovative Bridge Designs and Materials	4.4	6
Concrete Bridges	Performance of Embedded Prestressing Wires and Tendons	4.3	7
Bearings	Performance of Bridge Bearings	4.1	8
Decks	Performance of Precast Reinforced Concrete Deck Systems	4.0	9
Joints	Performance of Jointless Structures	4.0	10

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LTBP Study Topics (cont' d)

Category	Issue	Rating	Rank
Decks	Performance of Alternative Reinforcing Steels	3.9	11
Foundations	Direct, Reliable, Timely Methods to Measure Scour	3.5	12
Steel Bridges	Performance of Weathering Steels	3.5	13
Decks	Influence of Cracking on the Serviceability of HPC Decks	3.4	14
Risk	Risk and Reliability Evaluation for Structural Safety Performance	3.3	15
Foundations	Performance of Scour Countermeasures	3.3	16
Concrete Bridges	Performance of Prestressed Concrete Girders	3.3	17
Foundations	Unknown Foundation Types	3.1	18
Foundations	Performance of Structure Foundation Types	3.0	19
Functional	Criteria for Classification of Functional Performance	2.3	20
Substructure	Performance and Durability of MSE Walls	-	-
Substructure	Approach to abutment interaction and settlement	-	-

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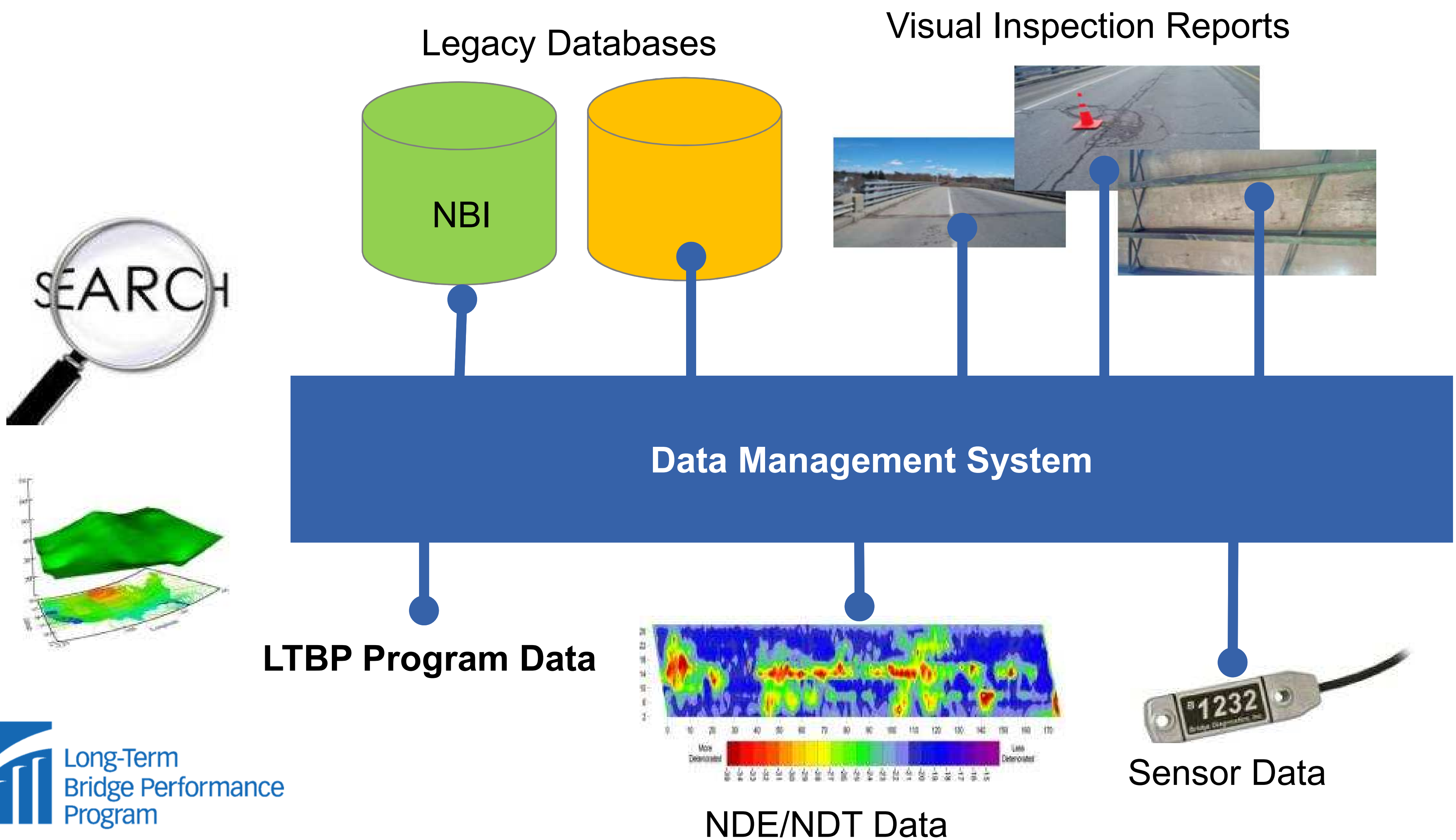
Data Infrastructure



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Inspection protocols

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Visual Inspection

CONCRETE CRACKING	
Data Collected: • Crack width, length and location • Determination of crack origin, if possible	**References:** Bridge Inspectors Reference Manual Bridge Inspector's Training Manual

Protocol

Process description/Data collection principle:

It is generally accepted that for reinforced concrete, only cracks over **0.008 in** are recorded as they allow water to penetrate into the concrete and cause corrosion of steel reinforcement. For pre-stressed concrete, which is not supposed to crack, detection of **0.004 in** cracks is required. It is also noted that in general, shrinkage cracks rarely exceed 0.004 inches. For the LTBP Program, structural and shrinkage cracks are important; it is therefore required to note all cracks over 0.004 in.

This implies that the inspector has **arms length access** to every part of the structure (arms length access is the general admitted distance from which cracks of this size are detectable).

Photo:

The crack information will be **entered directly into the database** to be analyzed later for Quality Assurance (QA). Crack information and analysis results are then sent to the database.

Whenever a crack is observed, the origins will be determined, if possible, amongst the following:

- Chemical: Alkali Silica Reaction (ASR); internal or external sulphate attack
- Structural (live or dead loads)
- Consequence from steel reinforcement or prestressing corrosion
- Creep or shrinkage
- Ground motion
- Fires, collisions, earthquakes, or other sudden and external solicitations

Inspection Equipment:

Access platform or ladder; hammer; brush; crack gauge; tape measure; digital camera; pen

Data collection methodology:

- Cleaning: If unsure, use the hammer to make certain it is not an area of delamination. Use the brush to uncover the crack, if necessary.
- Measurement, characteristics, and pictures: Measure the crack opening with the crack gauge at the greatest width and the crack length (from one end to the other, in straight line) with the tape measure. Report the measurements in the database. Mark the ends of the cracks on the bridge component with a pen. Take a photograph, capturing the whole crack as well as any surrounding information that would allow an understanding of the origin of the crack. Take additional photographs as necessary. Use the tape measure to locate the crack. For crack networks (crazing, scaling, etc.) or presenting the same

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LTBP – Key Features, Activities & Products

- **Pilot Bridge Phase**
- **Bridge Sampling (quantity, type, location, etc)**
- **Synthesis of Bridge Monitoring and Bridge Autopsy Methods**
- **Communication & Marketing Plan and Products**

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Pilot States and Bridge Types

New Jersey

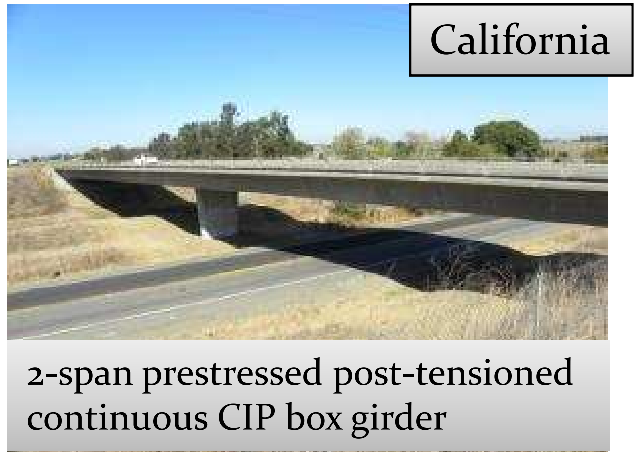
Simple span steel stringer

Virginia

Continuous steel stringer

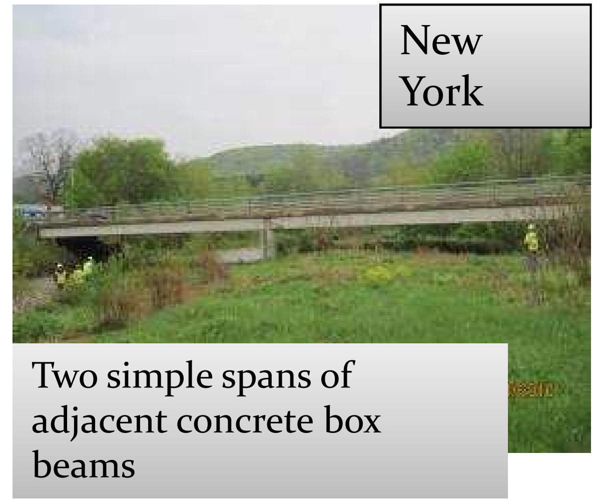
Utah

Simple span pre-stressed concrete stringer



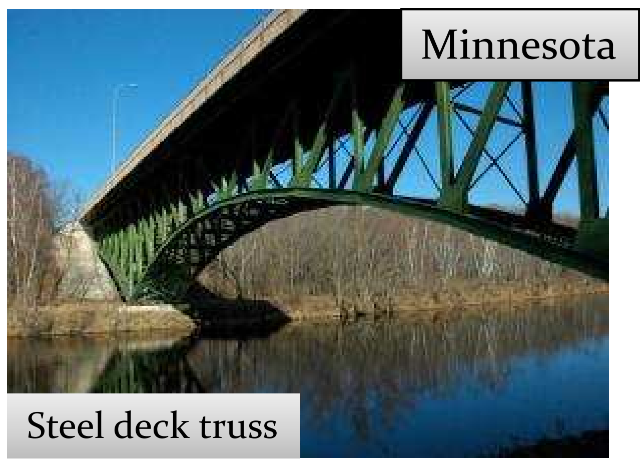
California

2-span prestressed post-tensioned continuous CIP box girder



New York

Two simple spans of adjacent concrete box beams



Minnesota

Steel deck truss

Florida

Precast, segmental post-tensioned concrete box beams

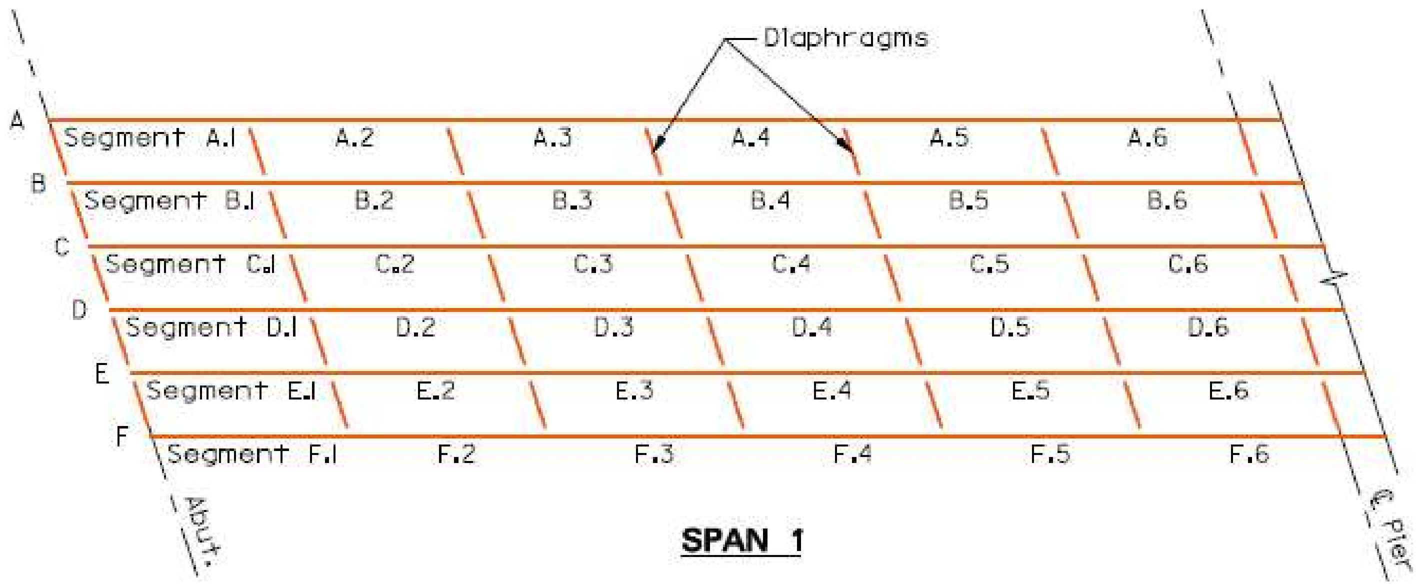
LTBP Pilot Bridges

Criteria	VA	UT	CA	NJ	MN	NY	FL
Structure Type	Continuous built-up steel girder	Single span AASHTO beams	Post-tensioned CIP Box Girder	Simple span steel girder bridge	Steel deck truss	Concrete adjacent box girders	Segmental Post-Tensioned Box
Year Built	1979	1976	1976	1969	1948	1990	1997
Deck Type	Bare CIP Concrete	CIP with membrane and asphalt overlay	CIP with thin polymer overlay	CIP deck with SIP forms*	Bare CIP Concrete	Bare CIP concrete	Precast Panels
Annual Average Daily Traffic	16,500	22,250	24,500	24,970	2,050	8,700	11,000
Percent Truck Traffic	6%	29%	21%	14%	8%	8%	4%
Miscellaneous		Integral Abutment and Weigh Station	8º Skew	WIM and Weather station	Historic Structure	24º Skew	Post-Tensioned Piers

* Overlay placed in September 2010

Segmental Inspection Method (BDS)

- Structure is broken down into small “segments”
  - Resolution can be <1% of structure for multi-girder system
- Allows defects to be accurately located
  - Deterioration effect on load capacity can be determined
  - Findings can be layered with results from other methods



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LTBP Pilot Study - Objectives

- Evaluate, validate & refine
  - Data collection protocols
  - Coordination and cooperation
  - Interface w/ database & database structure
  - Test and validate QA/QC measures for data transfer and storage
- Collect early useful data for the program

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Objectives of Pilot Phase Testing

- To demonstrate the ability of nondestructive evaluation (NDE) technologies and physical testing for detection and characterization of main deterioration types in bridge decks, in a consistent and reproducible manner.
- To examine the use of NDE and physical testing data in providing an objective assessment of the bridge deck condition and, thus, an objective assessment of changes with time.

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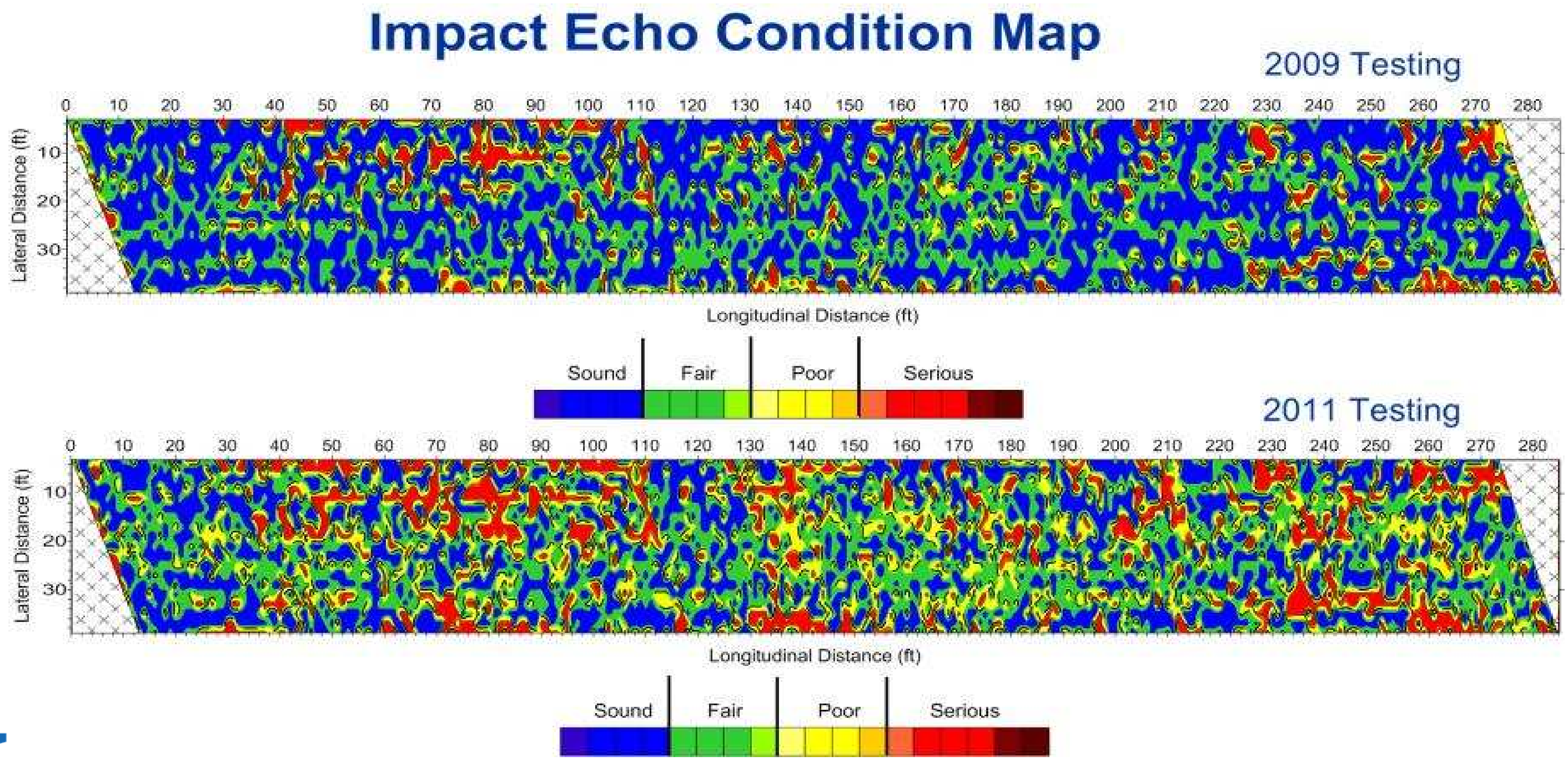
Delamination Comparison 9/2009 and 8/2011



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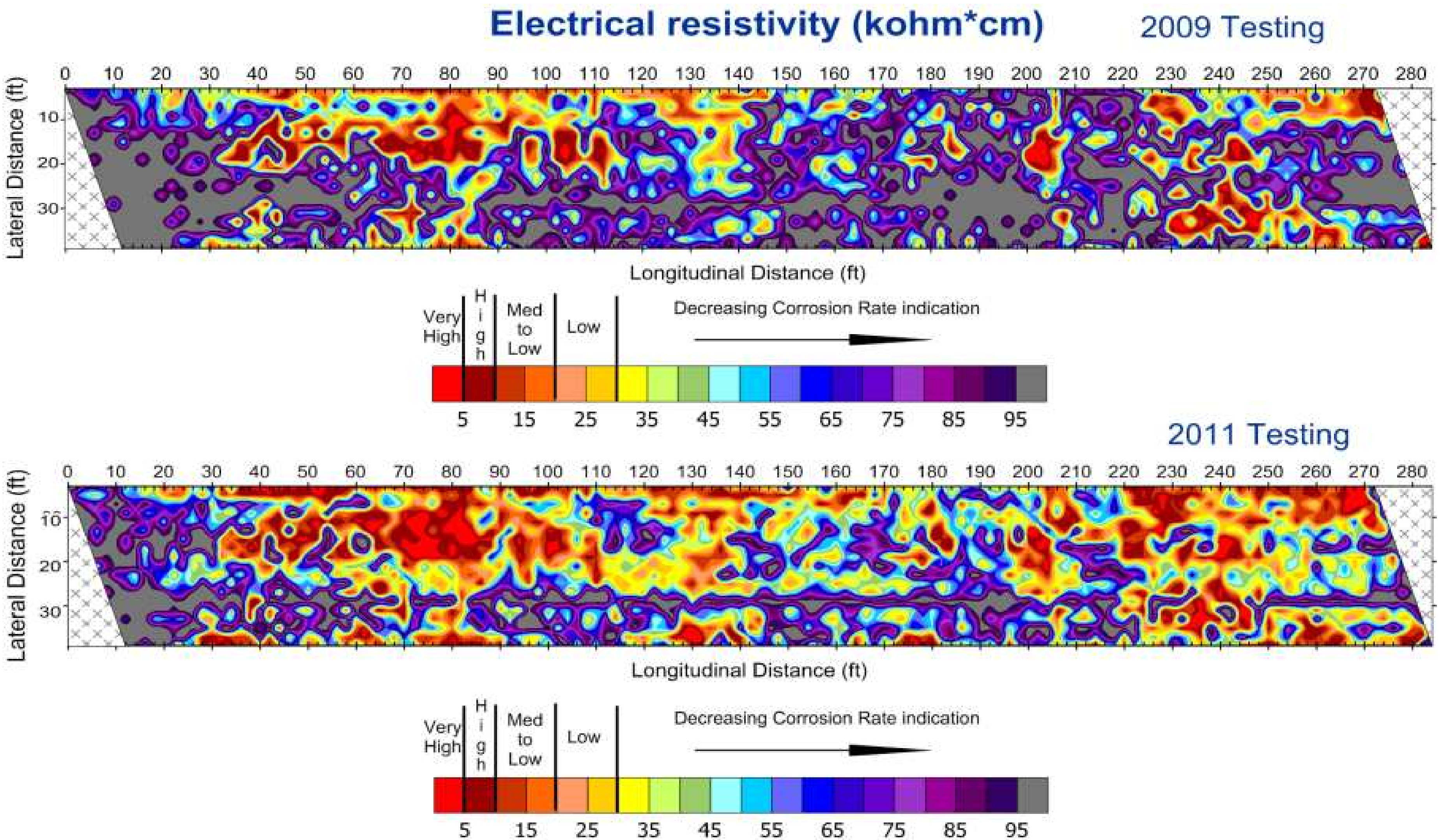
Electrical Resistivity Comparison 9/2009 and 8/2011



Pilot Study Results - Conclusions

- Advanced inspection by a complementary set of tools and monitoring methods provides a significantly more complete condition assessment of decks.
- Quantitative measurements minimize inspection subjectivity and enable objective rating of bridges.
- Well defined protocols and conventions, supported by quality control tools, are needed to ensure repeatability and reliability of data collected.

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Reference Bridge

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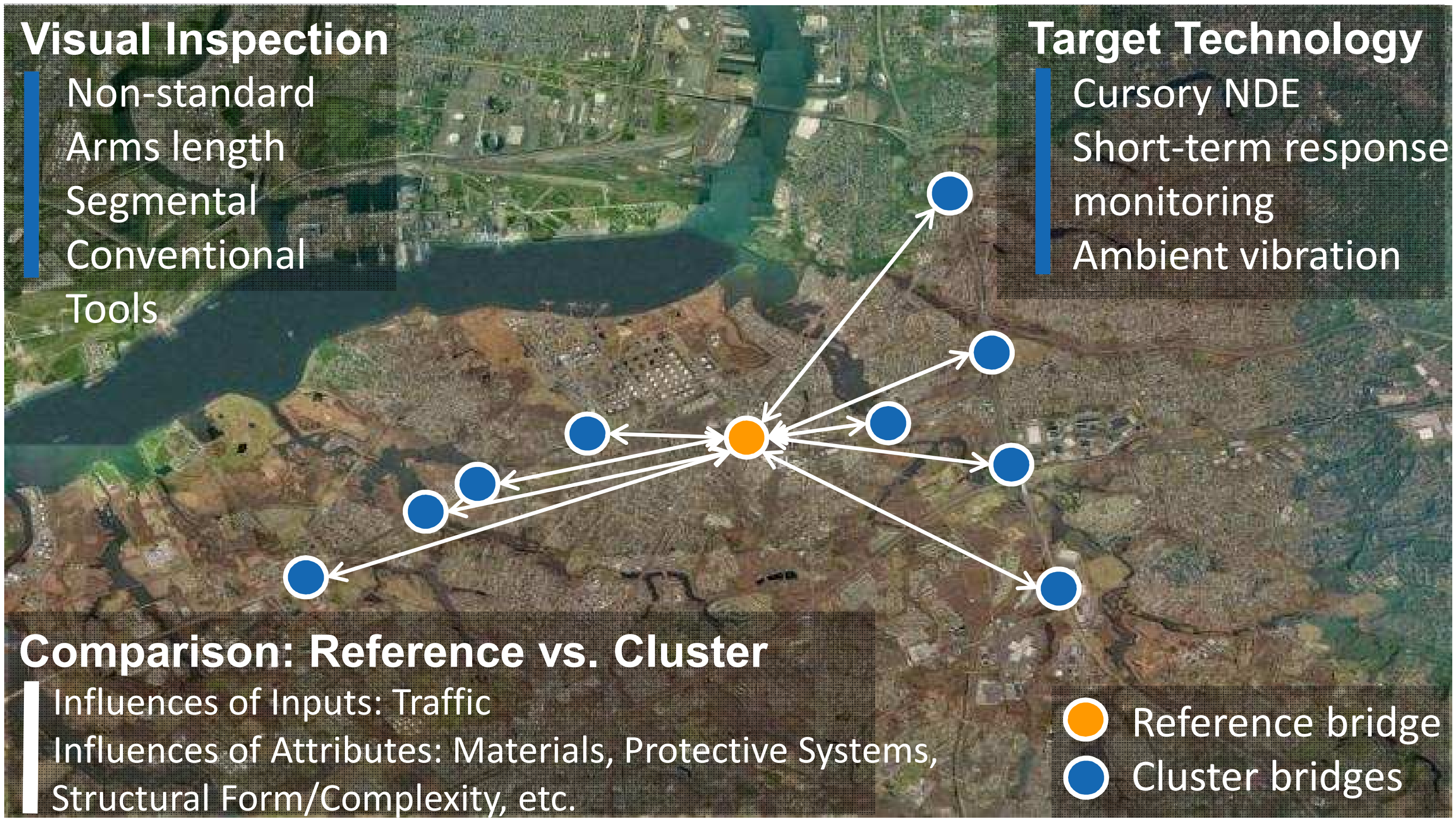
→| Approximate Scale: 200 ft |←

Reference Bridge and Supporting Cluster



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Approximate Scale: 30 mi

TRB Advisory Board Roster

States

- Ananth Prasad, Chairman, *Florida*
- Malcolm Kerley, Vice Chairman, *Virginia*
- Scott Christie, *Pennsylvania*
- Bruce Johnson, *Oregon*
- Jagesh Kapur, *Washington*
- Richard Land, *California*
- Sandra Larson, *Iowa*

Universities

- John Breen, *Univ. of Texas*
- Andrzej Nowak, *Univ. of Nebraska*

Consulting

- Harry Capers, *Arora & Assoc.*
- Gene Corley, *CTLGroup*
- Karl Frank, *Hirschfeld Industries*
- John Kulicki, *Modjeski and Masters*
- Kenneth Price, *HNTB Corporation*

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Roster (continued)

Liaisons

- Susan Lane, *Portland Cement Association*
- William McEleney, *National Steel Bridge Alliance*
- Kelley Rehm, *AASHTO*
- Ted Scott, *American Trucking Associations*

FHWA

- Hamid Ghasemi, *LTBP Program Manager*
- Firas Sheikh Ibrahim , *Infrastructure Management Team*

TRB

- Stephen Godwin, *Director, Studies and Special Programs*
- Waseem Dekelbab, *Senior Program Officer*
- Robert Raab, *Senior Program Officer*
- Claudia Sauls, *Senior Program Assistant*

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LTBP State Coordinators Committee

- One DOT designated Coordinator per State
- One or two meetings per year
  - Review/critique program activities
  - Input on current and possible future studies
  - Coordination of pool fund studies
- One or more webinars per year
- Travel funded by FHWA

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Most Common Forms of Deterioration, Damage or Functional Issues*

- Decks (**cracking, spalling**, **corrosion**, delamination, corrosion, rutting, poor aggregates, freeze-thaw)
- Deck joints (secondary issues – bearing, girder end, and substructure corrosion
- Structural steel paint
- Substructure corrosion and scour, and timber decay
- Steel fatigue, bearing failure, p/s strand corrosion, deck drains, membrane leakage, grout key leakage

** IN PRIORITY ORDER*

Desired Outcomes of LTBP

- Best practices
- Modeling
- Quantify impacts of specific repair and preservation actions on service life
- Estimating the time period for needing routine preservation actions
- Process for sharing data nationally
- Benefits of maintenance and preservation actions
- Relating impacts of damage and deterioration to overall system response or stiffness

Questions

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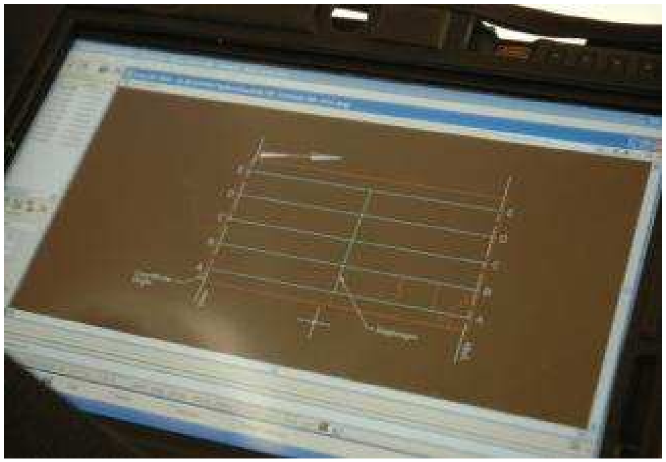
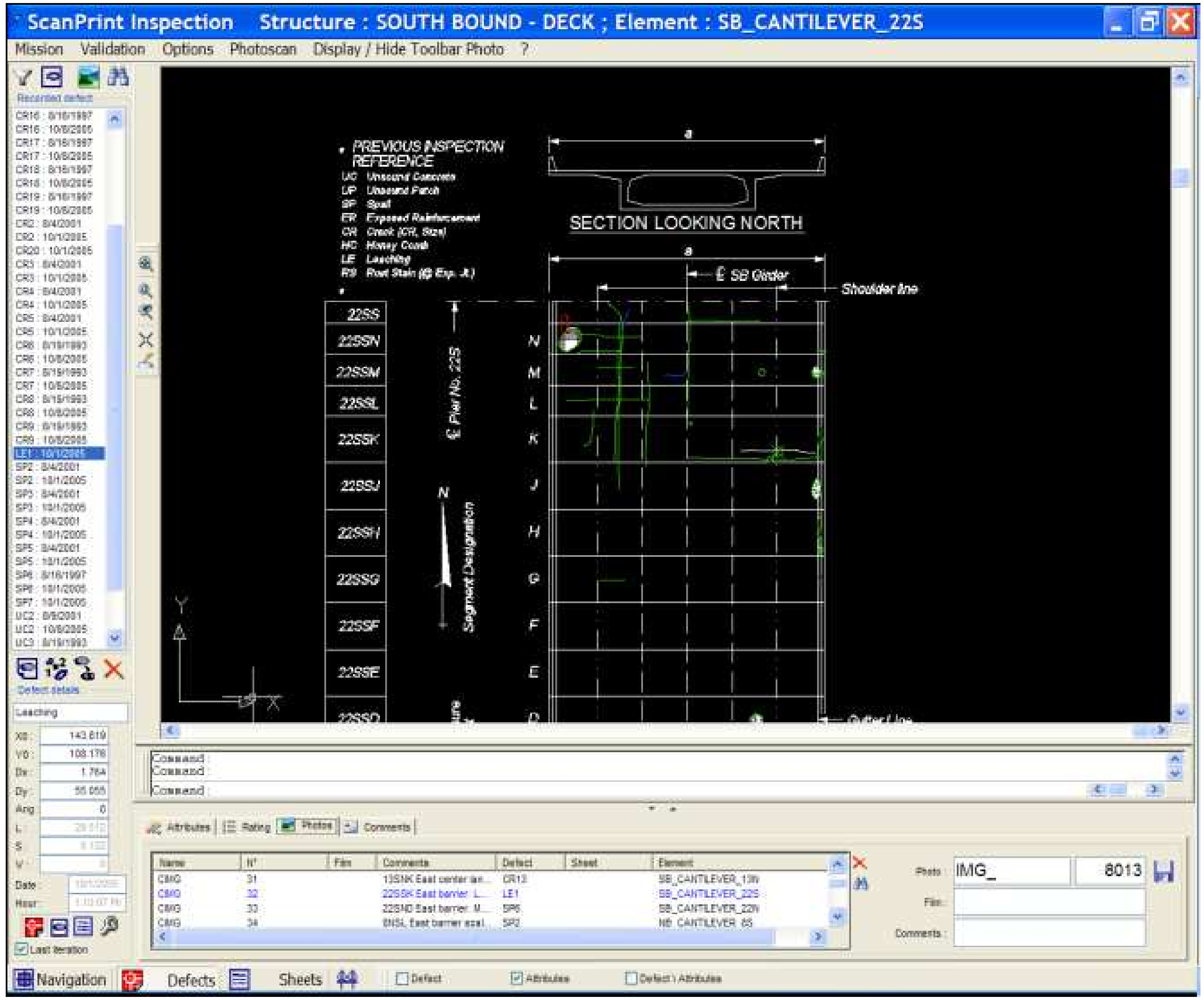
On-site Data Collection – ScanPrint





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Task 1.8: Communication & Marketing Plan and Products – Activities

- LTBP website at DOTs, academia and/or industry

  http://www.tfhrc.gov/ltbp
- Quarterly Newsletters
- Tech Briefs
  - 6 to 8 page documents on LTBP topics
  - Available on LTBP website
- Annual ½ day workshop at TRB – next on January 26, 2012
- Papers, presentations, and/or exhibit booths at engineering conferences
- Webinars

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Bridge Deck Deterioration

Corrosion | Delamination | Concrete Degradation

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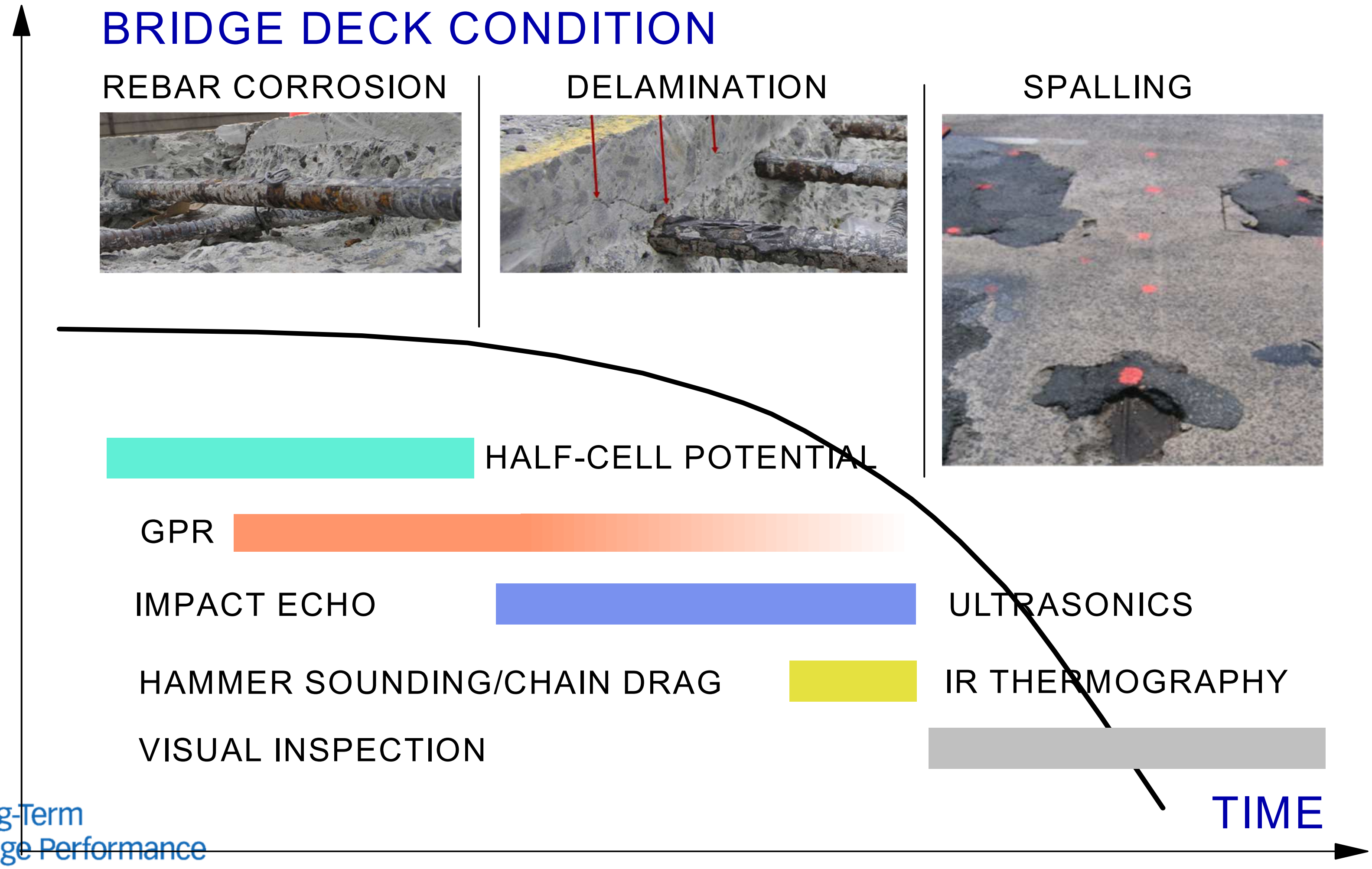
Bridge Deck Condition Assessment



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Corrosion Testing and Physical Sampling

Corrosion Testing

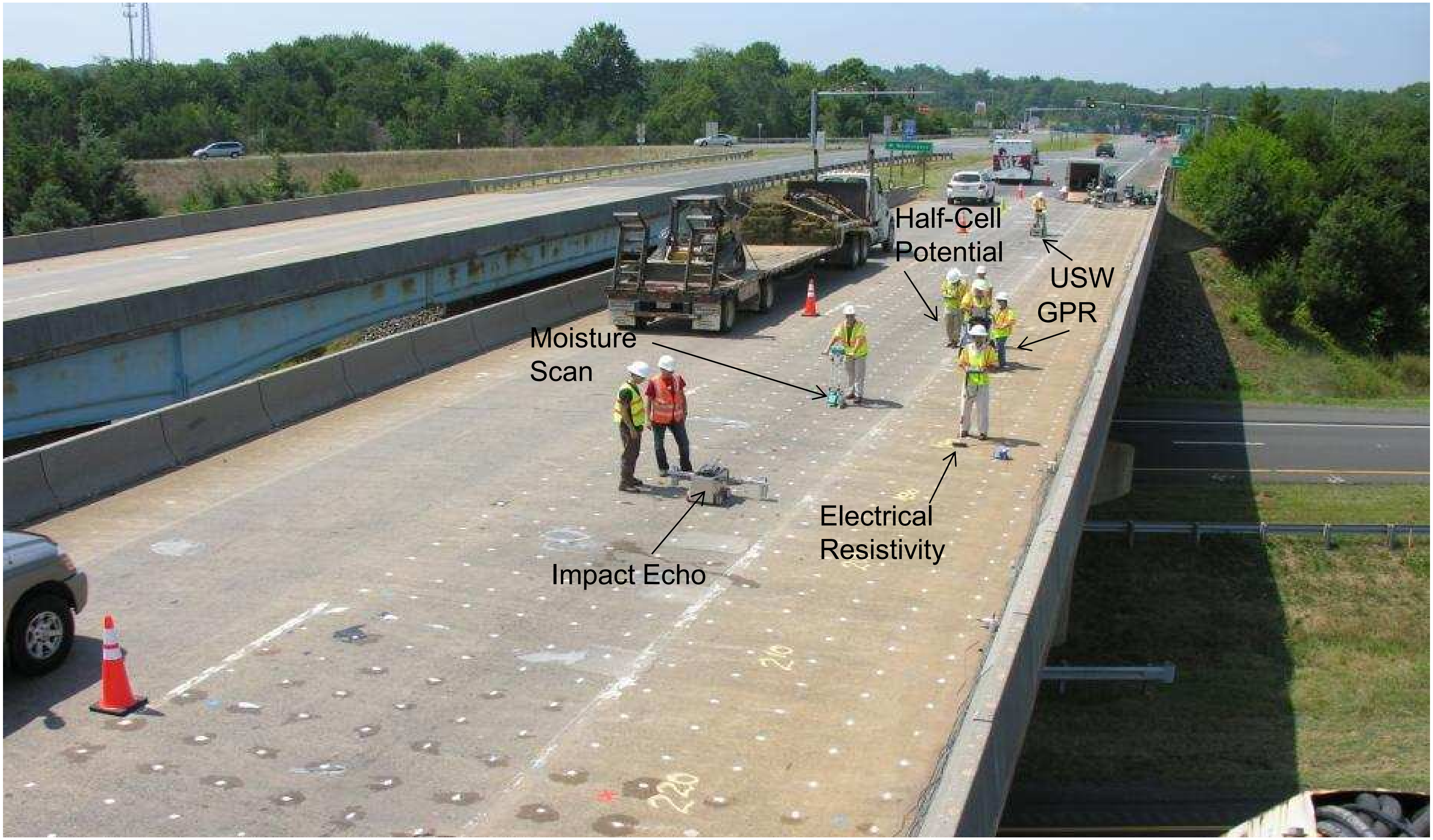
- Reinforcement Steel Continuity
- Concrete Resistivity – 2-point and 4-point
- Electrical Potential - Half-cells
- Rate - Linear polarization and Electrochemical Impedance Spectroscopy

Physical Sampling

- Chloride concentration – powdered concrete profiles
- Cores to determine:
  - Visual - inspection of concrete and reinforcement
  - Gravimetric - Unit weight, absorption and moisture content
  - Permeability - Electrical “Rapid Chloride Permeability” Test
  - pH and Carbonation
  - Concrete elastic moduli - Static and dynamic modulus
  - Compressive and tensile strength

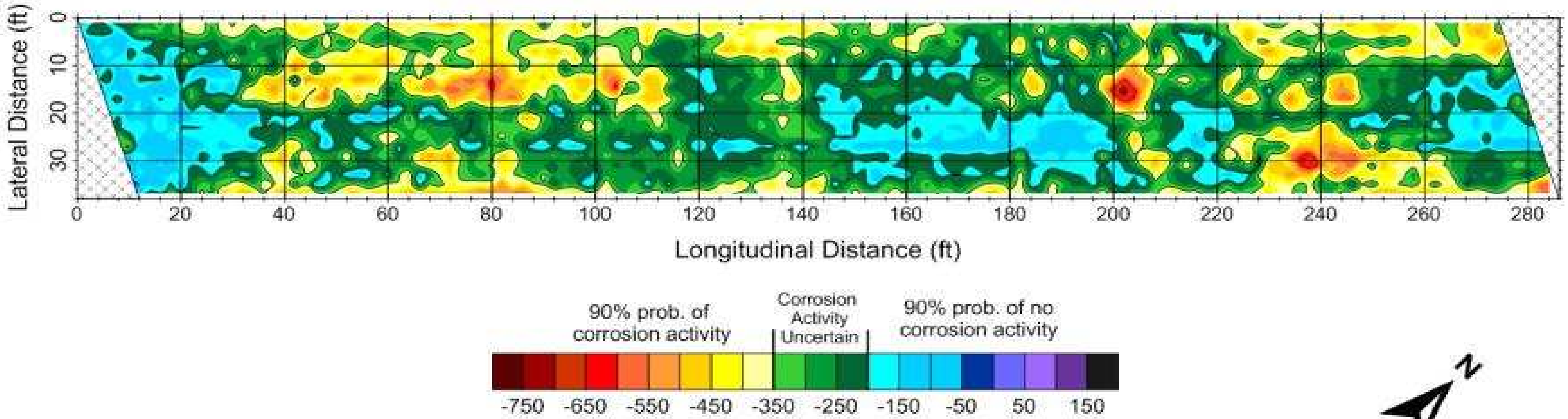
NDE Data Collection – Test Grid

Virginia Bridge

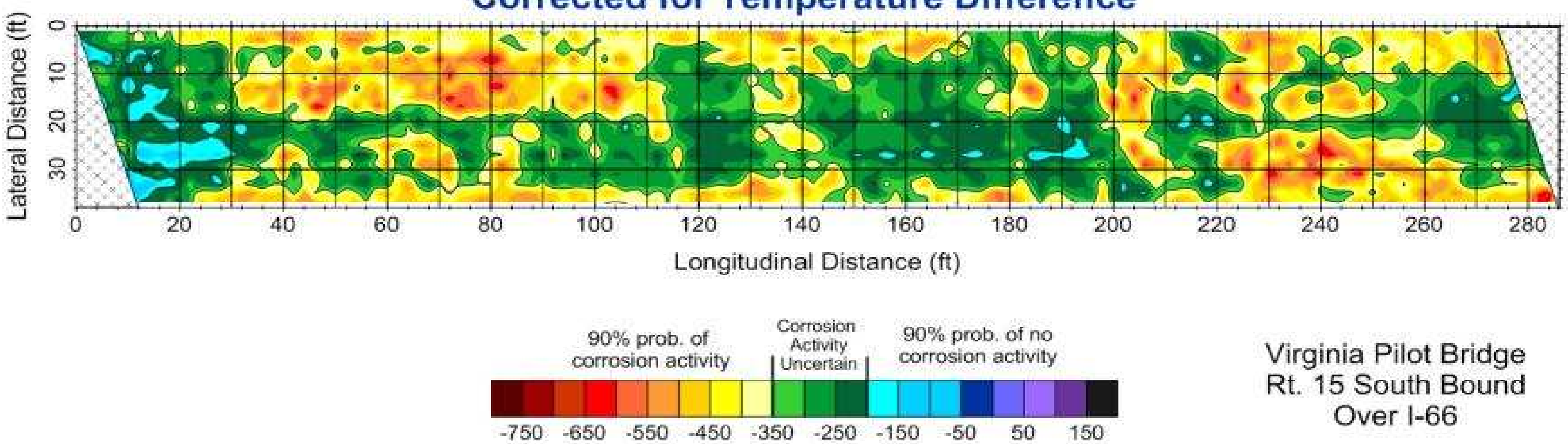


Half Cell Potential Comparison 9/2009 and 8/2011

Half-Cell Potential (mV), September 2009



Half-Cell Potential (mV), August 2011
Corrected for Temperature Difference

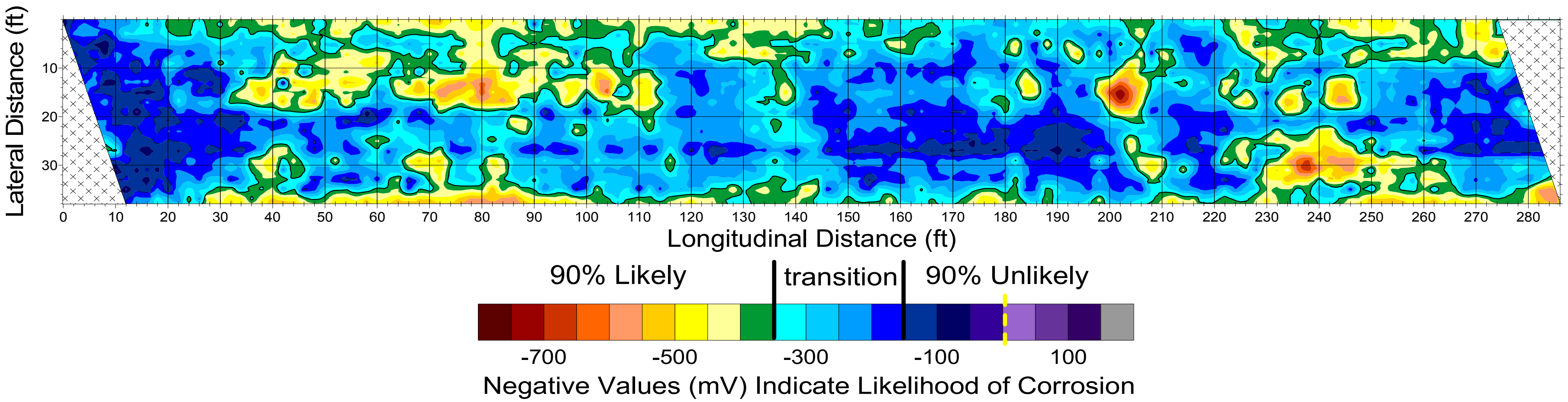


Virginia Pilot Bridge
Rt. 15 South Bound
Over I-66

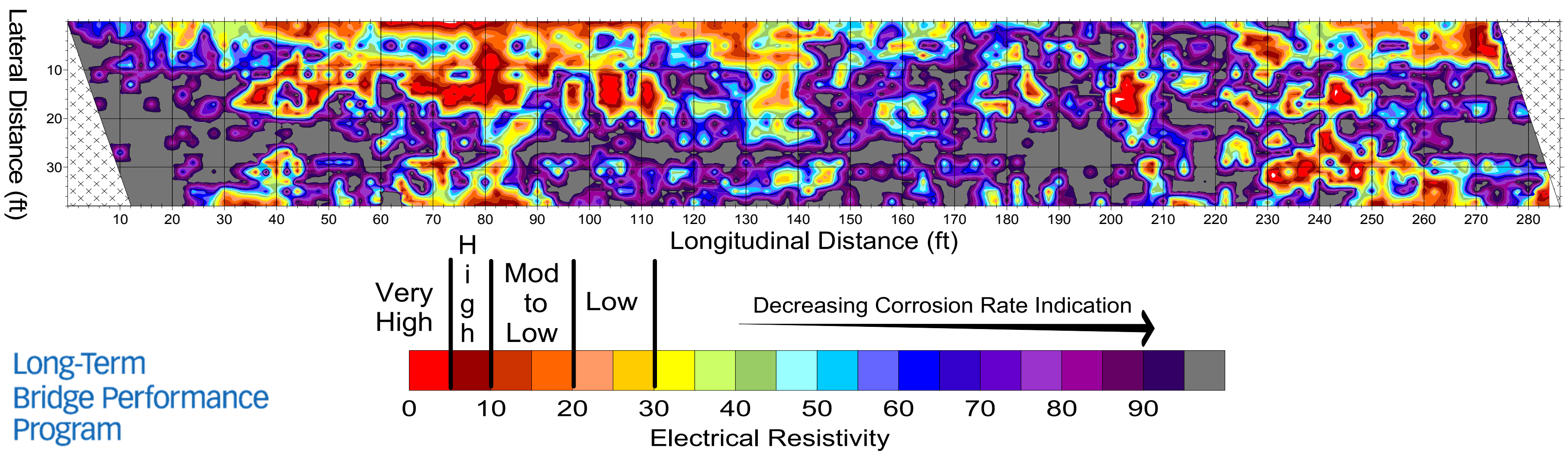
Condition Assessment of Deck

Virginia Bridge

Half-Cell Corrosion Potential (mV)



Electrical Resistivity (kOhm*cm)



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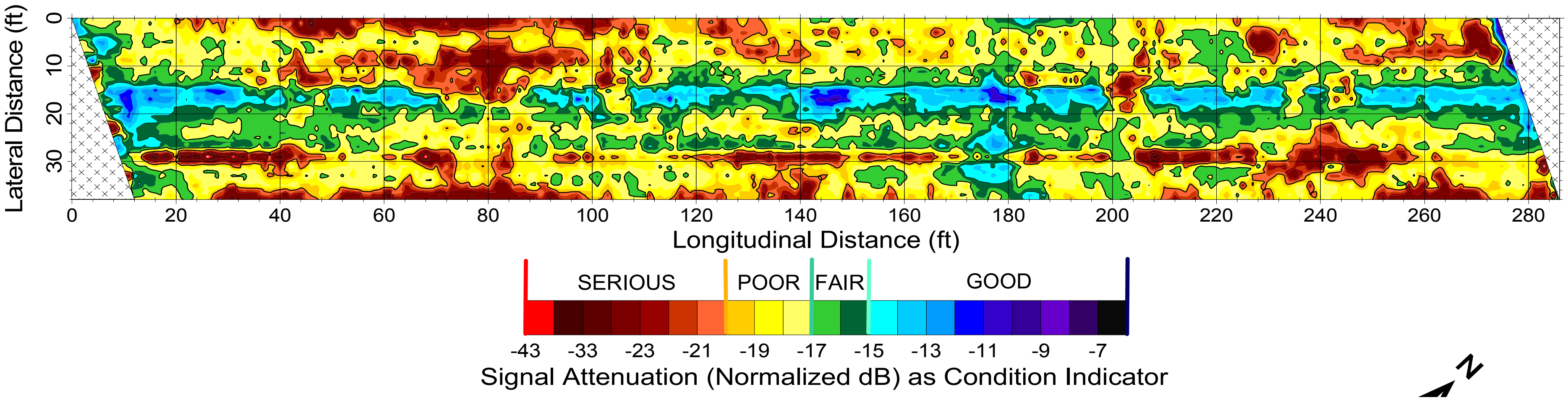
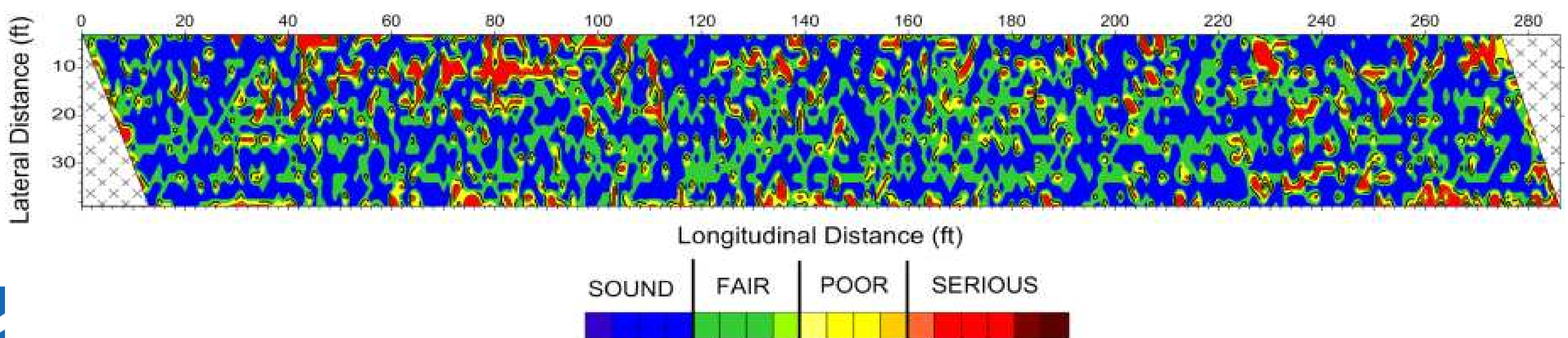
Condition Assessment of Deck

Virginia Bridge

Depth-Corrected GPR Condition Map



Impact Echo Delamination Assessment

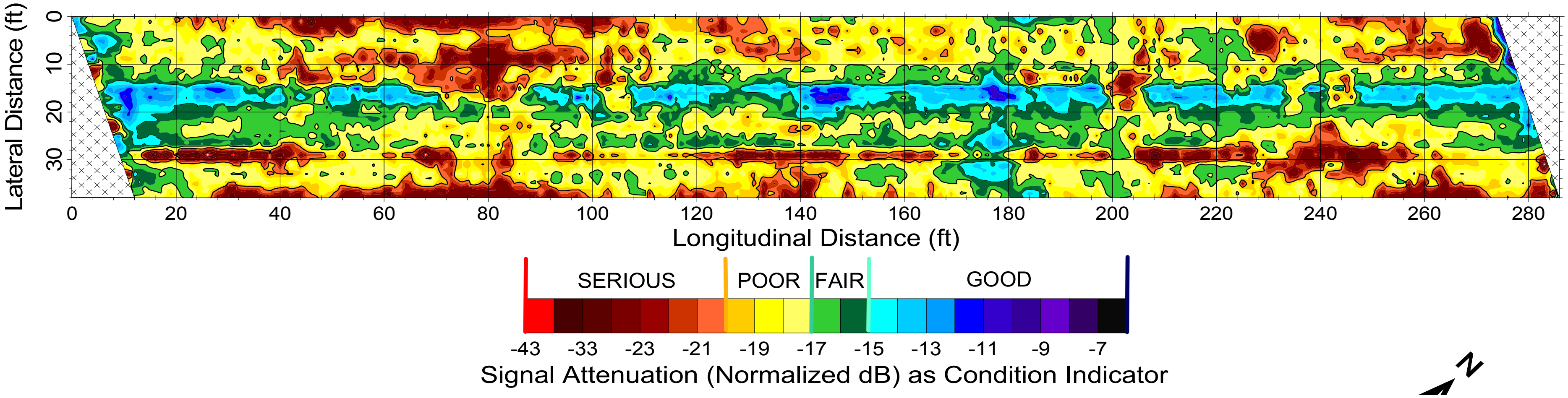


Bridge Performance Program

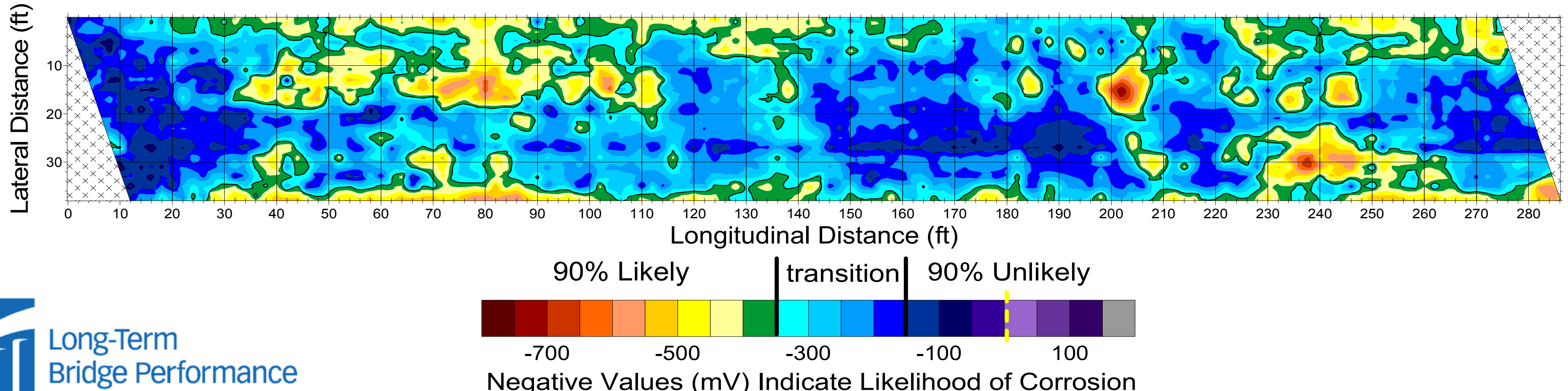
Condition Assessment of Deck

Virginia Bridge

Depth-Corrected GPR Condition Map



Half-Cell Corrosion Potential (mV)



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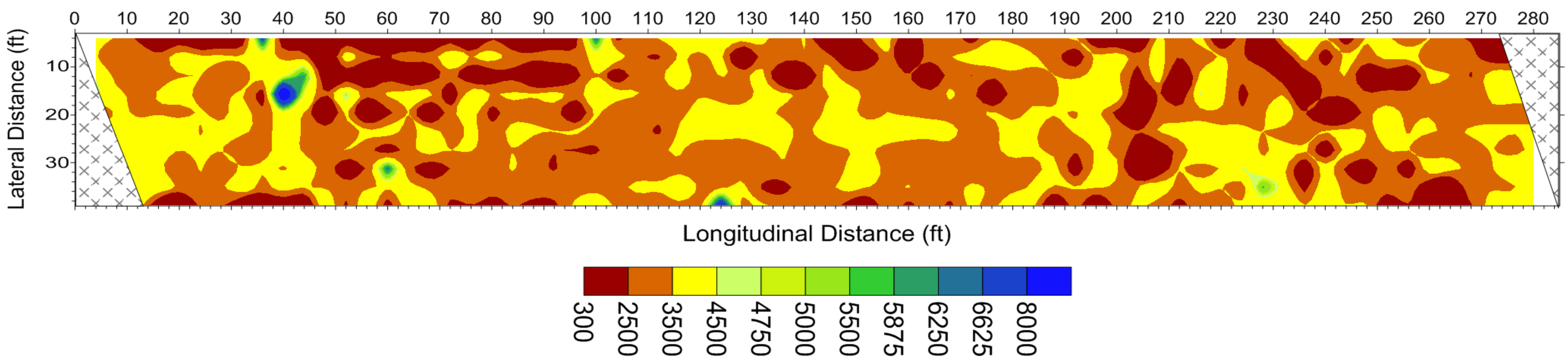
Condition Assessment of Deck

Virginia Bridge

USW Obtained Concrete Modulus (ksi)



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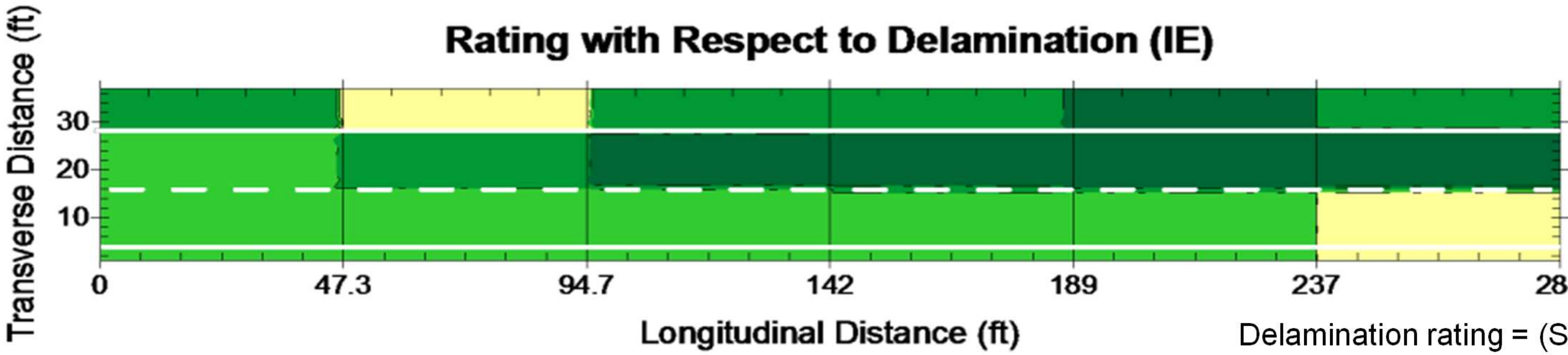
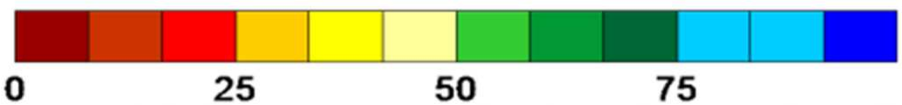
Segmentation and Condition Rating

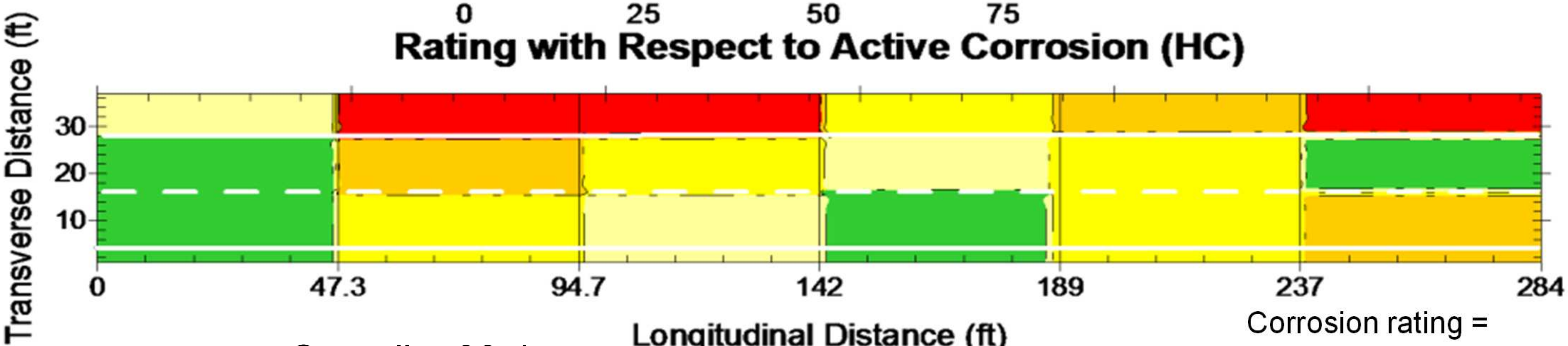
Virginia Bridge



Delamination rating = (Serious area*0 + Fair/Poor area*50 + Sound area*100) / Total area

Overall – 70





Overall – 39.4

Corrosion rating = (Likely area*0 + Transition area*50 + Unlikely area*100) / Total area

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Comparison of Pilot Phase Bridges Through Condition Rating

	VA	NJ	CA	NY	MN
Active Corrosion	39.4	79.4	100	8.4	26.2
Delamination Assessment	70.0	82.0	72.0	65.7	77.5
Concrete Degradation	48.1	67.5	72.2	54.2	58.3
Combined Rating	52.5	76.3	81.4	42.7	54.0

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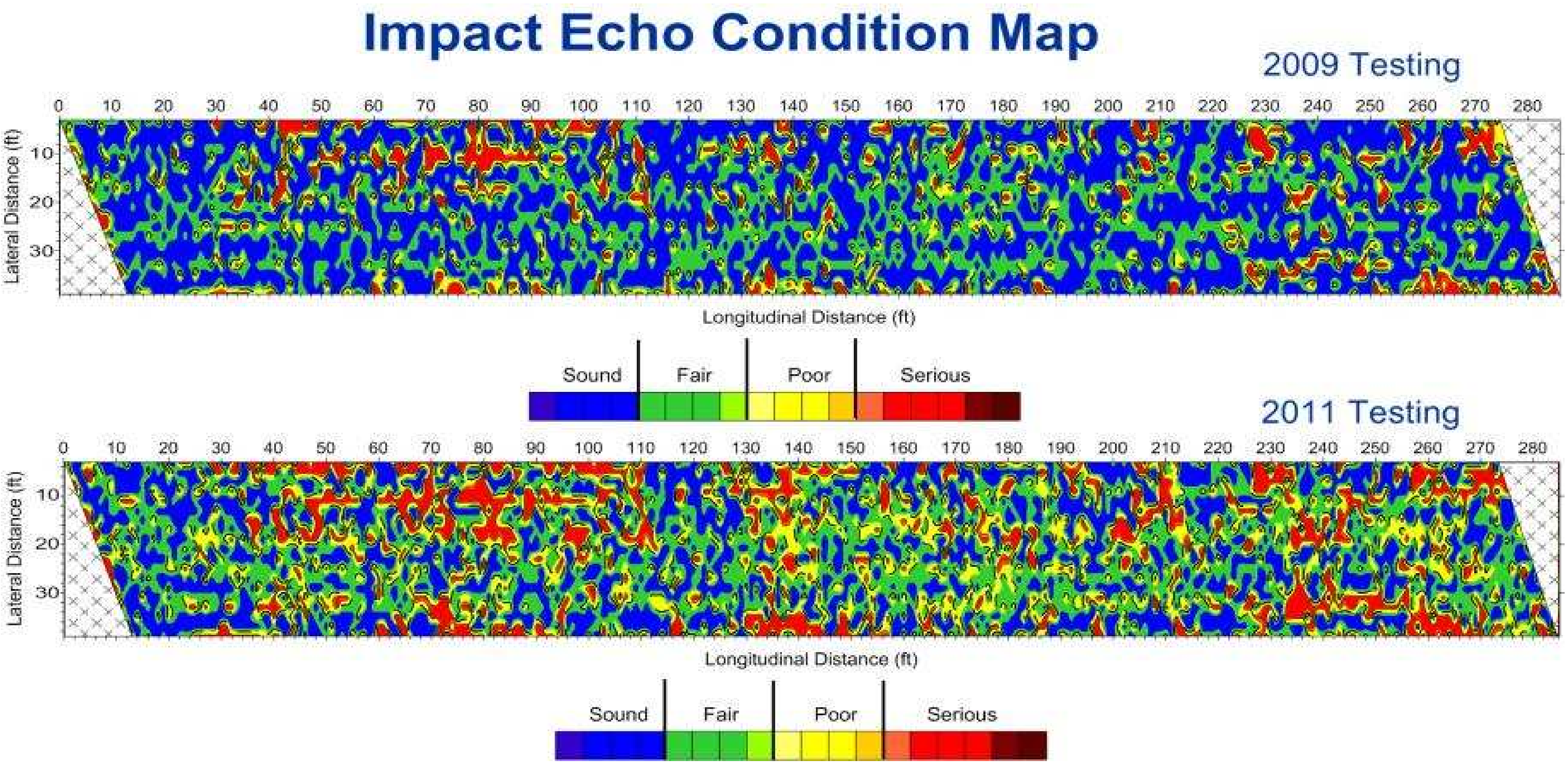
Delamination Comparison 9/2009 and 8/2011



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Comparison of 2009 and 2011 Condition Ratings of the Virginia Bridge

	2009	2011
Active Corrosion	39.4	28.1
Delamination Assessment	70.0	57.2
Concrete Degradation	48.1	35.3
Combined Rating	52.5	40.2

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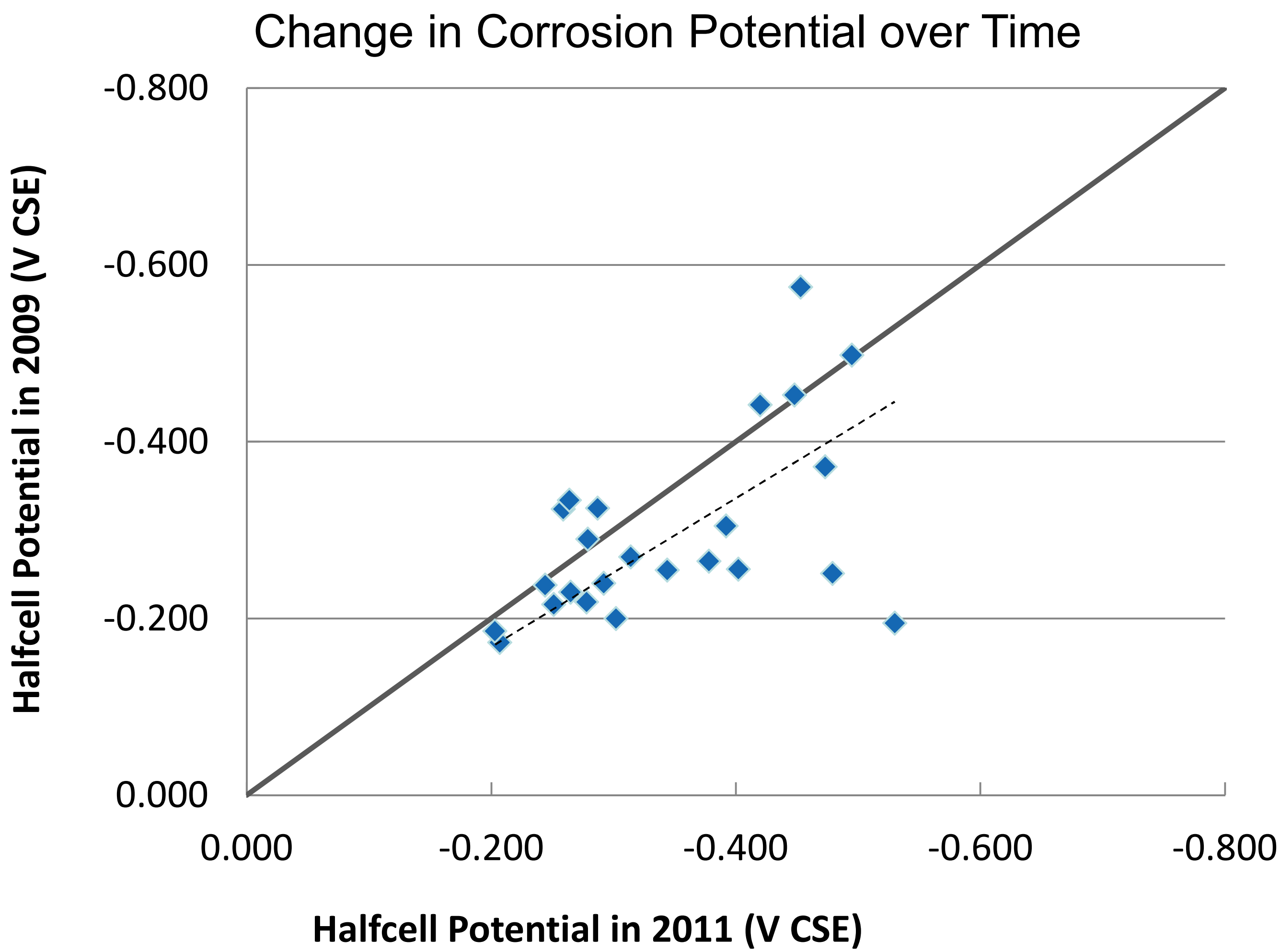
Interpretation of Corrosion Data

Virginia Bridge



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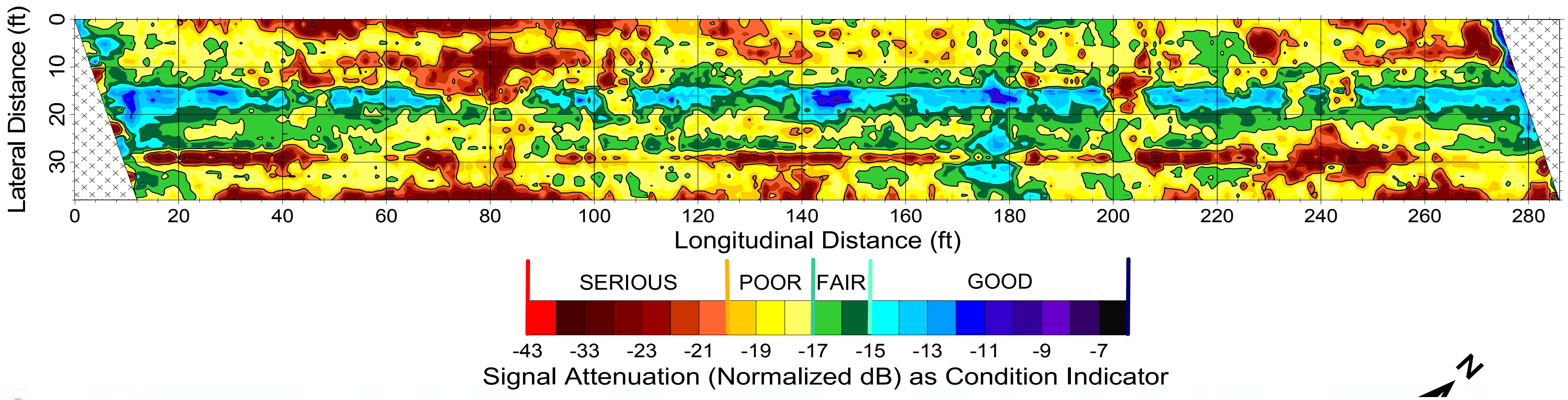
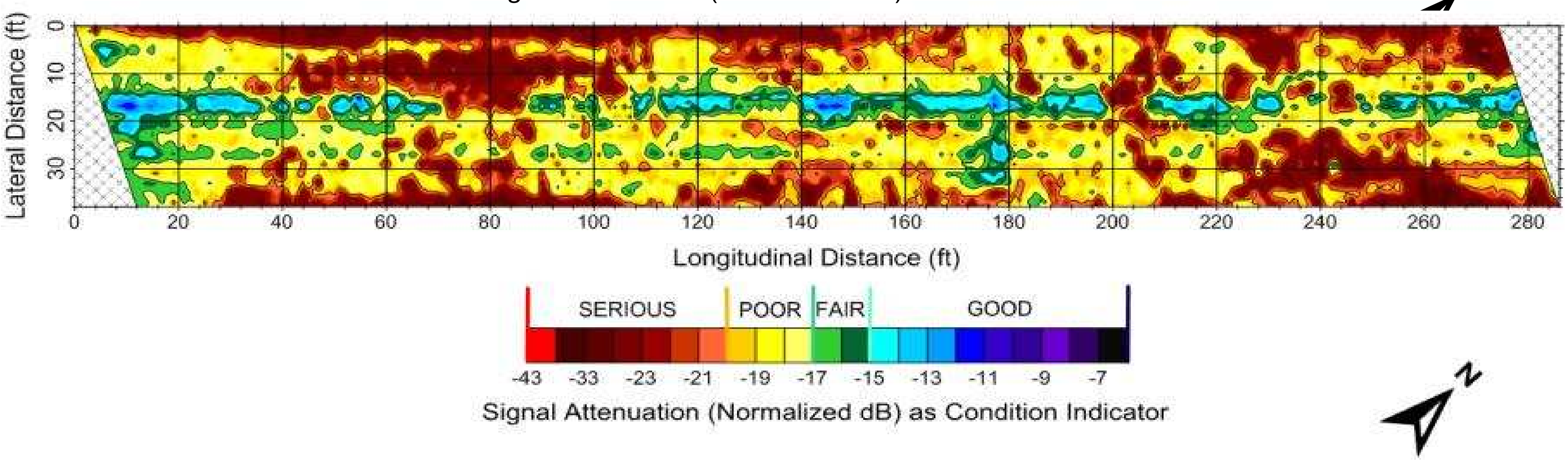
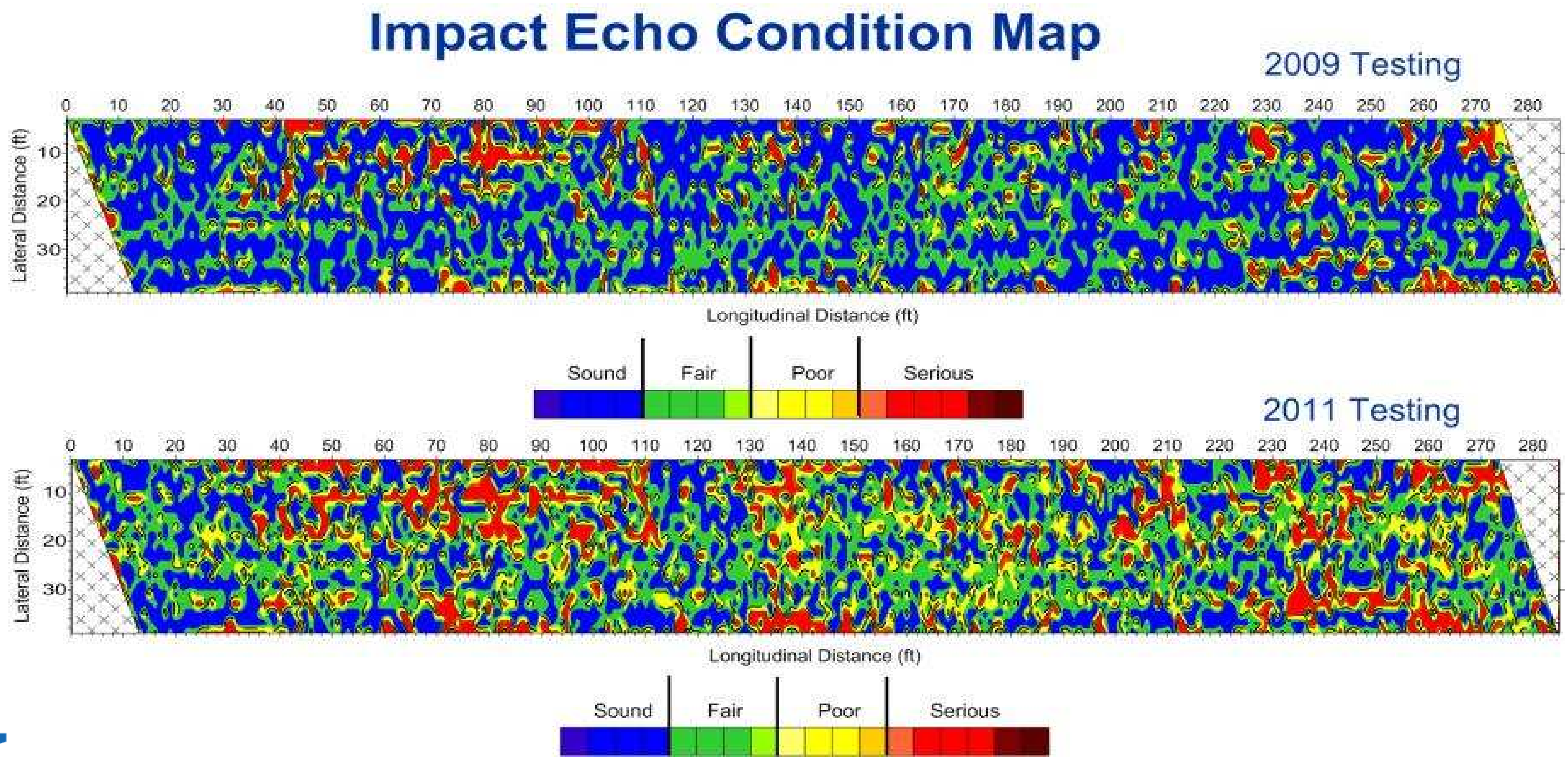
GPR Condition Assessment Comparison 9/09 and 8/11

Depth-Corrected GPR Condition Map





Delamination Comparison 9/2009 and 8/2011



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Pilot Phase –
Live Load & Dynamic Testing

Tommy Cousins, Virginia Tech
Carin Roberts-Wollmann, Virginia Tech
Marv Halling, Utah State University
Paul Barr, Utah State University

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Objectives

- To establish baseline bridge condition
- To develop live load and dynamic testing protocols
- To utilize dynamic and live load testing results to evaluate bearing conditions of the pilot bridges
- To use dynamic and live load testing results to refine finite element models of each bridge
- To investigate dynamic methods resulting in minimal traffic interruption or service disruption.

Live Load Testing

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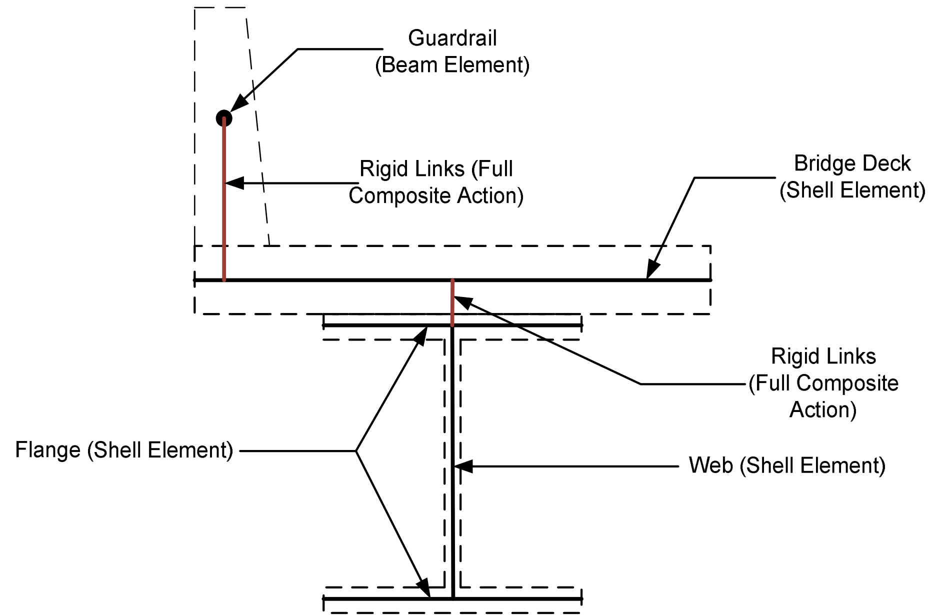
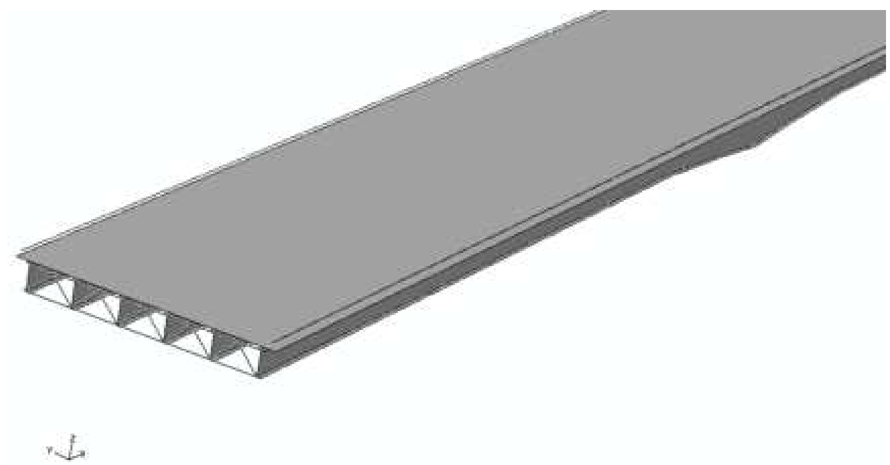
Virginia Bridge

Finite Element Modeling

- Refined Model Includes Haunched/tapered Girders, Bracing, Concrete Deck, Supports
- Support Conditions are Roller-Pin-Roller





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Conclusions

- Re-Test shows repeatability of results
- For Virginia Bridge deck deterioration not adversely affecting structural behavior
- Dynamic Testing is extremely helpful in validating bearing condition of a bridge, and, in the case of the California bridge, improving the load rating
- Dynamic testing can be performed without lane closures if conditions require

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Typical Load Application

Truck type varies

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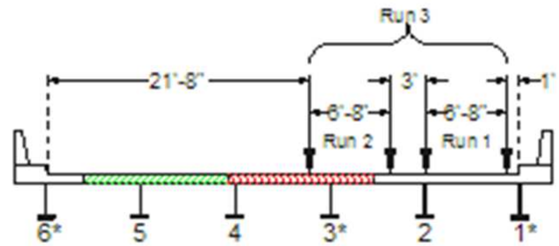
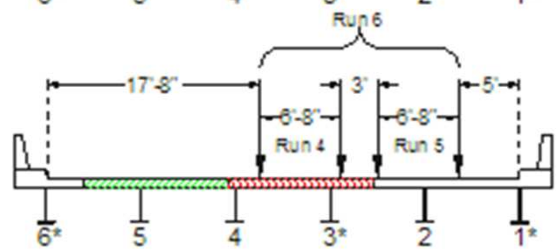
Quasi-Static Test Plan
Looking in Direction of Traffic

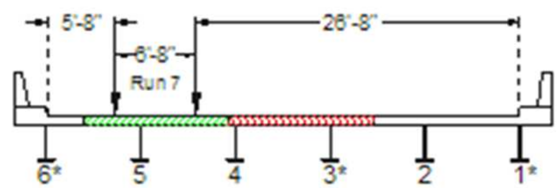
1. Maximize loading on Girder 1 and Girder 2.



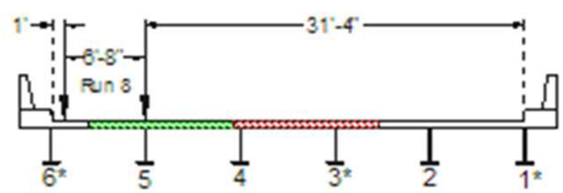
2. Maximize loading in Girder 3 given the placement of Run 4 in the center of the traffic lane.



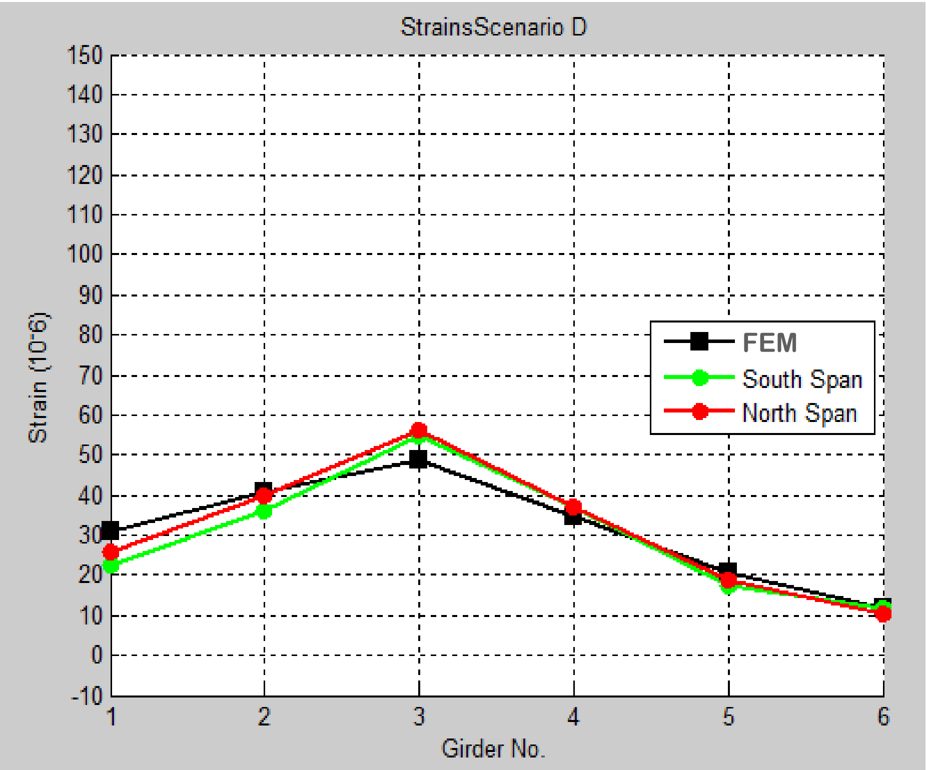
3. Run 7 centers a truck in the left hand lane.

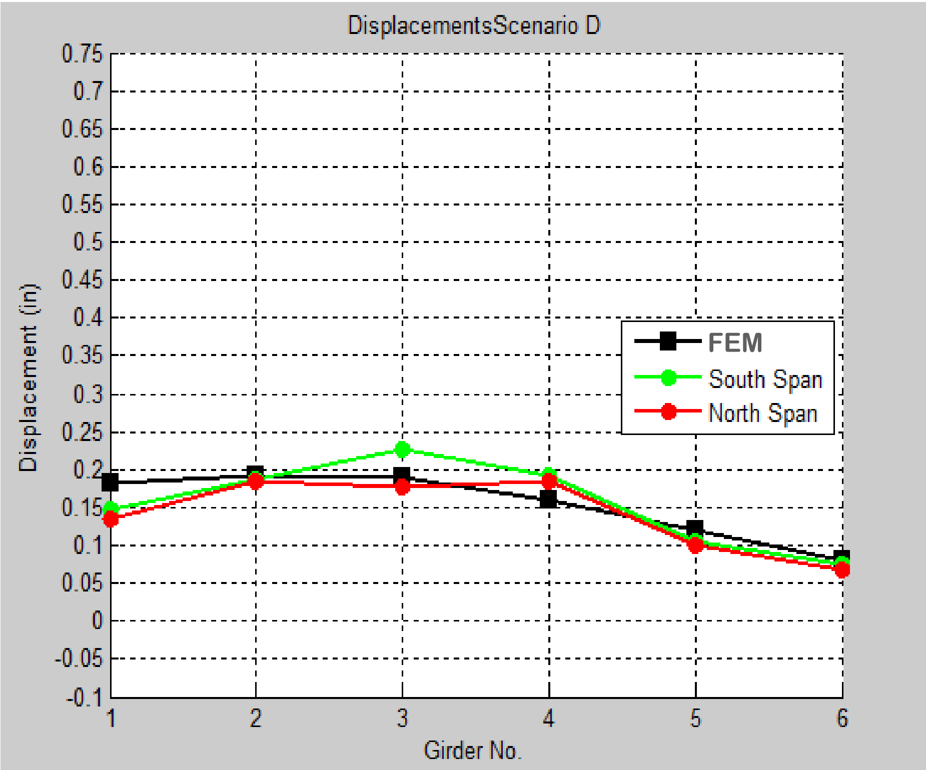


4. Maximize loading on Girder 6 while observing the required traffic control restrictions



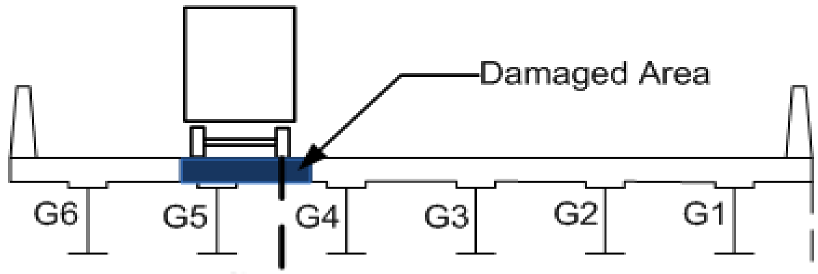
Live Load Test Data Comparison with Finite Element Model





Long-Term Bridge Performance Program

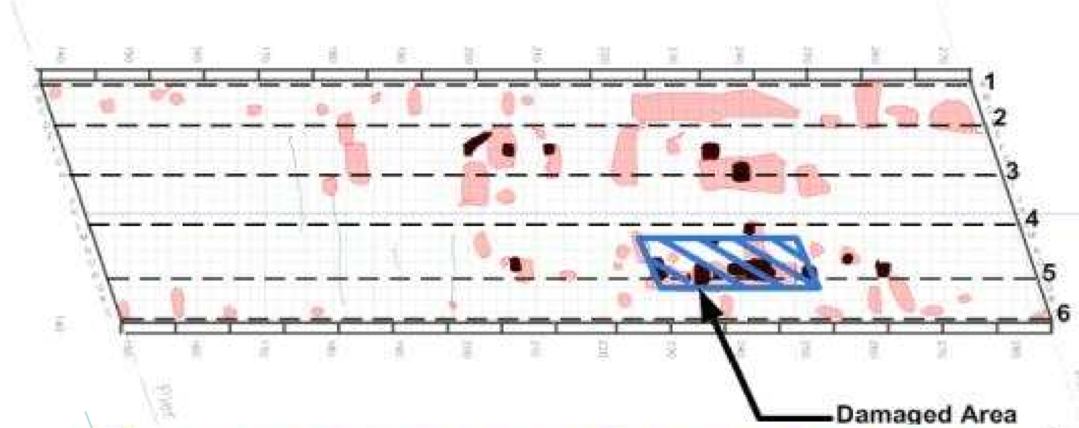
Virginia Bridge



Visual Inspection:

light red - delaminations

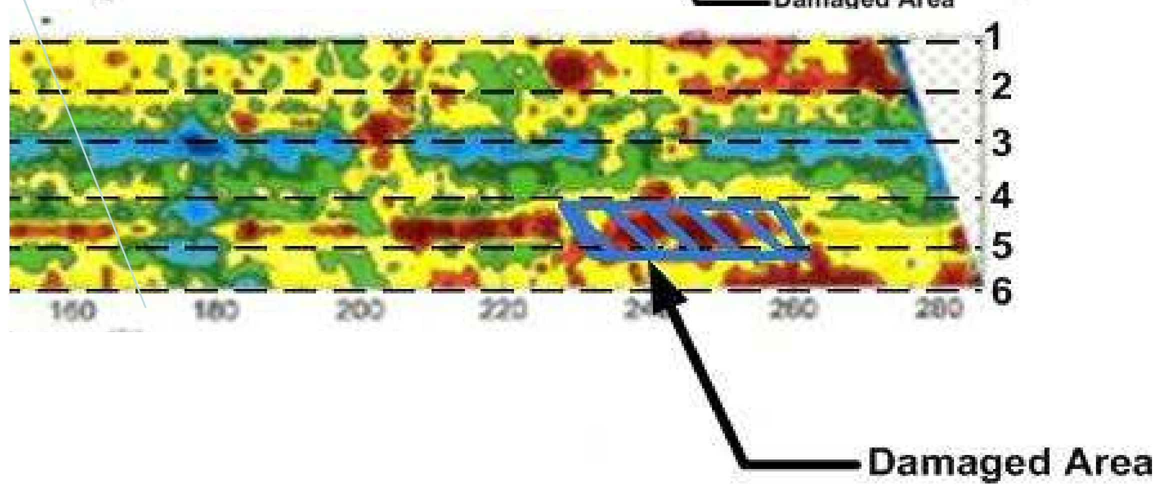
dark red - patches



GPR Condition Map:

yellow - poor

red - serious



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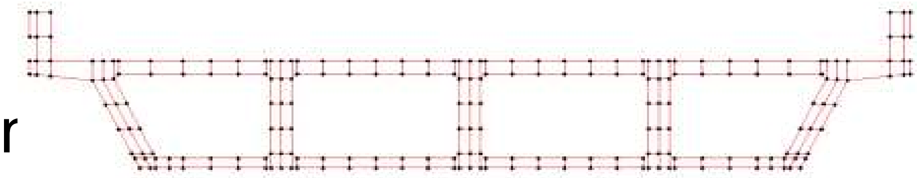
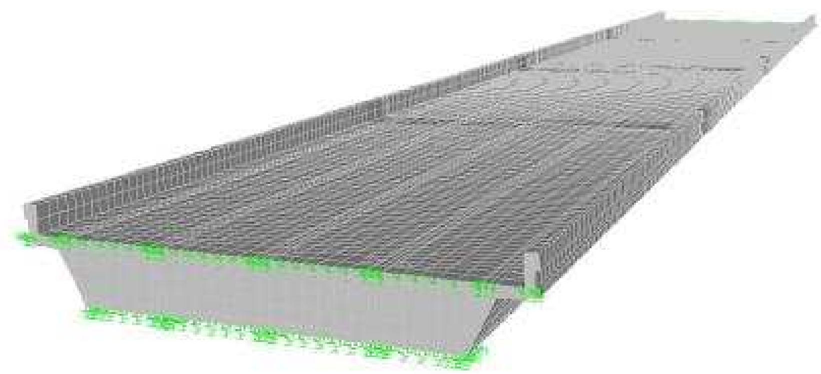
California Bridge

Finite-Element Model

- 8 node solid elements
  - 3 degrees of translational freedor
  - Fine mesh
    - Low aspect ratio
    - 1ft longitudinal node spacing
- Abutment/Pier supports modelec as springs
- Post-tensioning strands modelec as tendons





Long-Term Bridge Performance Program

Federal Highway Administration Long-Term Bridge Performance Program

Pilot Phase – Long Term Monitoring

Marvin Halling, Utah State University
Paul Barr, Utah State University
Tommy Cousins, Virginia Tech
Carin Roberts-Wollmann, Virginia Tech

Long-Term Bridge Performance Program

Federal Highway Administration
Long-Term Bridge Performance Program

High Priority Performance Issues

Michael C. Brown, Ph.D., P.E.
Virginia Center *for* Transportation Innovation & Research

Long-Term
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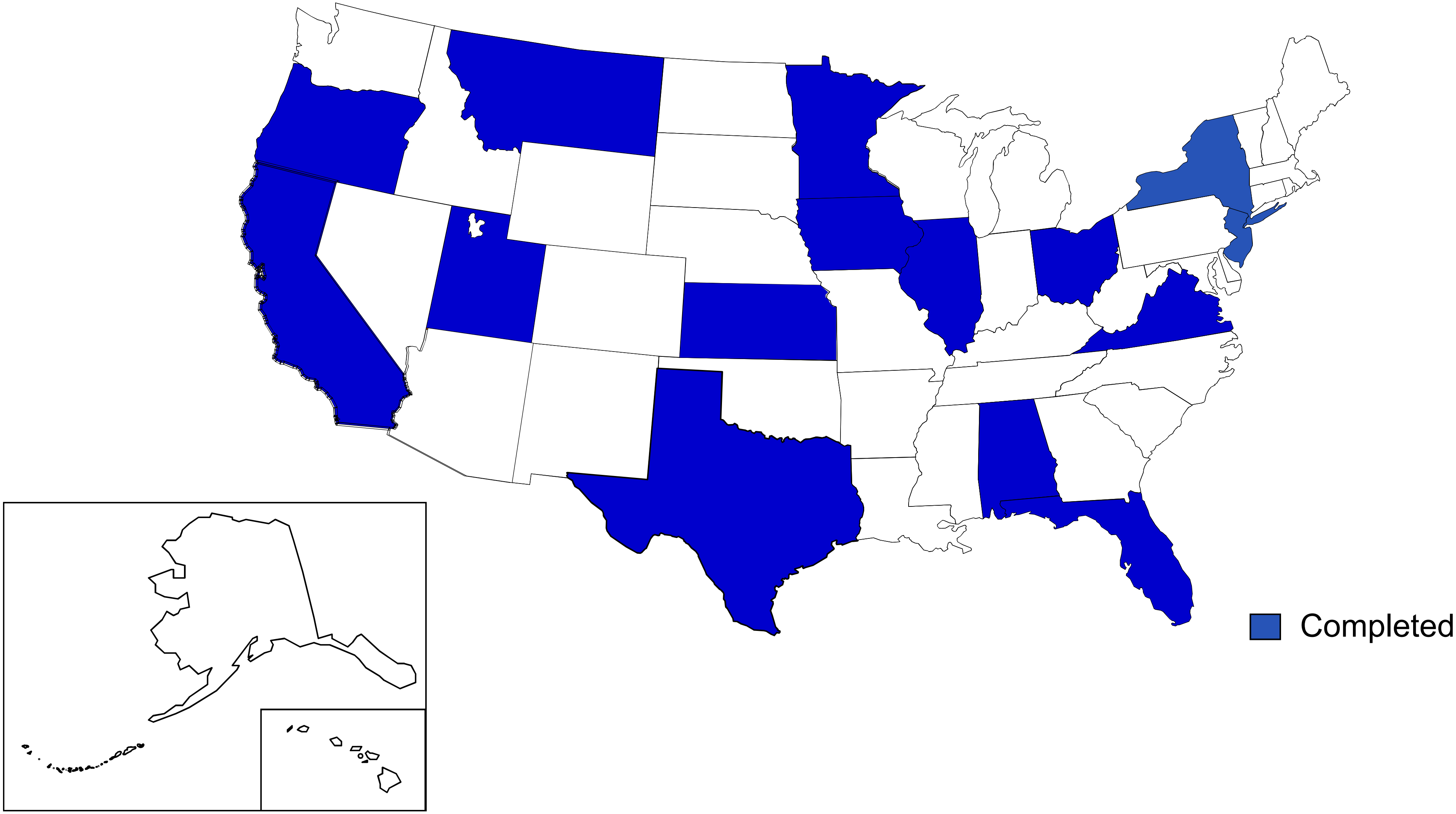
Focus Groups - Participating State DOTs



Observations: Bridge Performance Issues

- **Decks:**
  - Cracking
  - Delaminations and spalling
  - Pot holes
  - Fatigue cracks
  - Weathering and rot
  - Leaking or failed joints

- **Superstructures:**
  - Cracking
  - Corrosion
  - Deterioration of paint systems
  - Girder end deterioration
  - Steel fatigue
  - Box girder hinges
  - Joint deterioration
  - Impact of girders and railings
  - Concrete pop-outs due to freezing

- **Substructures:**
  - Scour
  - Cracking
  - Corrosion, spalling and delamination
  - ASR
  - Seismic
  - Bearing pedestals deterioration
  - Frozen, misaligned or failed bearings

- **Functionalities:**
  - Serviceability issues
  - High traffic loads and volumes
  - Low load ratings
  - Bridge width not matching road width
  - Inadequate vertical clearance
  - Drainage, impact damage

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Example:

Data Types and Priorities vs Studies

		Untreated Concrete Decks	Bridge Deck Treatments	Cracking on Decks	Precast Deck Systems	Alternative Reinforcing	Bridge Deck Joints	Jointless Structures	Bridge Bearings	Concrete Super/Substructures	Prestressed Concrete Girders	Embedded wires and tendons
Concrete Superstructure		**14**	**14**	**14**	**14**	**0**	**14**	**14**	**14**	**12**	**17**	**15**
	Load testing	2	2	2	2		2	3	2	2	3	2
	Strain measurements	2	2	2	2		3	3	3	2	3	3
	Deflection measurements	2	2	2	2		3	2	3	2	3	3
	Differential deformation	2	2	2	2		3	3	3	3	3	2
	Camber loss or growth	1	1	1	1		2	3	2		3	3
	Delamination	1	1	1	1		1	1	1	3	2	2
	Cracks	1	1	1	1		1	1	1	3	3	2
Environmental Data		**8**	**9**	**8**	**7**	**8**	**7**	**1**	**6**	**8**	**7**	**7**
	Temperature	3	3	3	3	3	3	3	3	2	3	2
	Relative Humidity	2	2	2	2	2				2	2	2
	Precipitation - Rainfall	2	2	2	2	2	2		1	1	1	1
	Precipitation - Snowfall	3	3	3	3	3	3		1	1	1	1
	Freeze-Thaw	3	3	3	3	3	3		2	2	2	1
	Marine environment	2	2	2	2	2	1		1	3	1	3
	Air quality - Industrial pollutants	1	1	1						1		

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Illustrative Example

Bridge Type: Simply-supported, multi-girder steel bridges

Guiding questions related to deck performance…

Intra-cluster

- **What is the influence of various deck protective systems on deck performance?**
- **What is the influence of ADTT on deck performance**
- **What is the influence of structural form (skew, span length) on deck performance**

Inter-cluster

- **What is the influence of environmental influences on deck performance?**
- **What is the influence of maintenance practices on deck performance**

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Federal Highway Administration Long-Term Bridge Performance Program

Reference and Cluster Bridge Concept

Franklin Moon, PhD
Intelligent Infrastructure Systems, LLC
Drexel University

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Non-Technical Challenge: Uncertainty, uncertainty, uncertainty

Open Questions…

- Breadth versus Depth? Is there a minimum threshold required for meaningful results?
- What funding will be available? What future constraints will need to be addressed?
- Will near-term or mid-term technology improvements mitigate this challenge?

Requisite Non-Technical Attributes

- **Scalability** – amenable to expansion and contraction
- **Flexibility** – depth and frequency of data collection efforts, use of technology
- **Continuous, Vigilant Assessment** – development of rigorous feedback mechanisms to enable course-corrections/refinements

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Three-Tiered Approach

Tier I – Reference Bridge

- **1 to 2 bridges**
- **Representative of the most common inputs and attributes of selected bridge type**
- **Rendered completely transparent through the application of the state of the art assessment and monitoring approaches**

Tier II – Cluster Bridges

- **25 to 30 bridges**
- **Selected to allow the investigation of various input and attribute influences on performance**
- **Performance tracked through targeted use of technology and enhanced visual inspection procedures**

Tier III – Population Bridges

- **250 to 500 bridges**
- **Selected to provide context, assess variability, and ensure that the cluster bridges are representative**
- **Performance tracked through standard element-level inspection**

Reference Bridge

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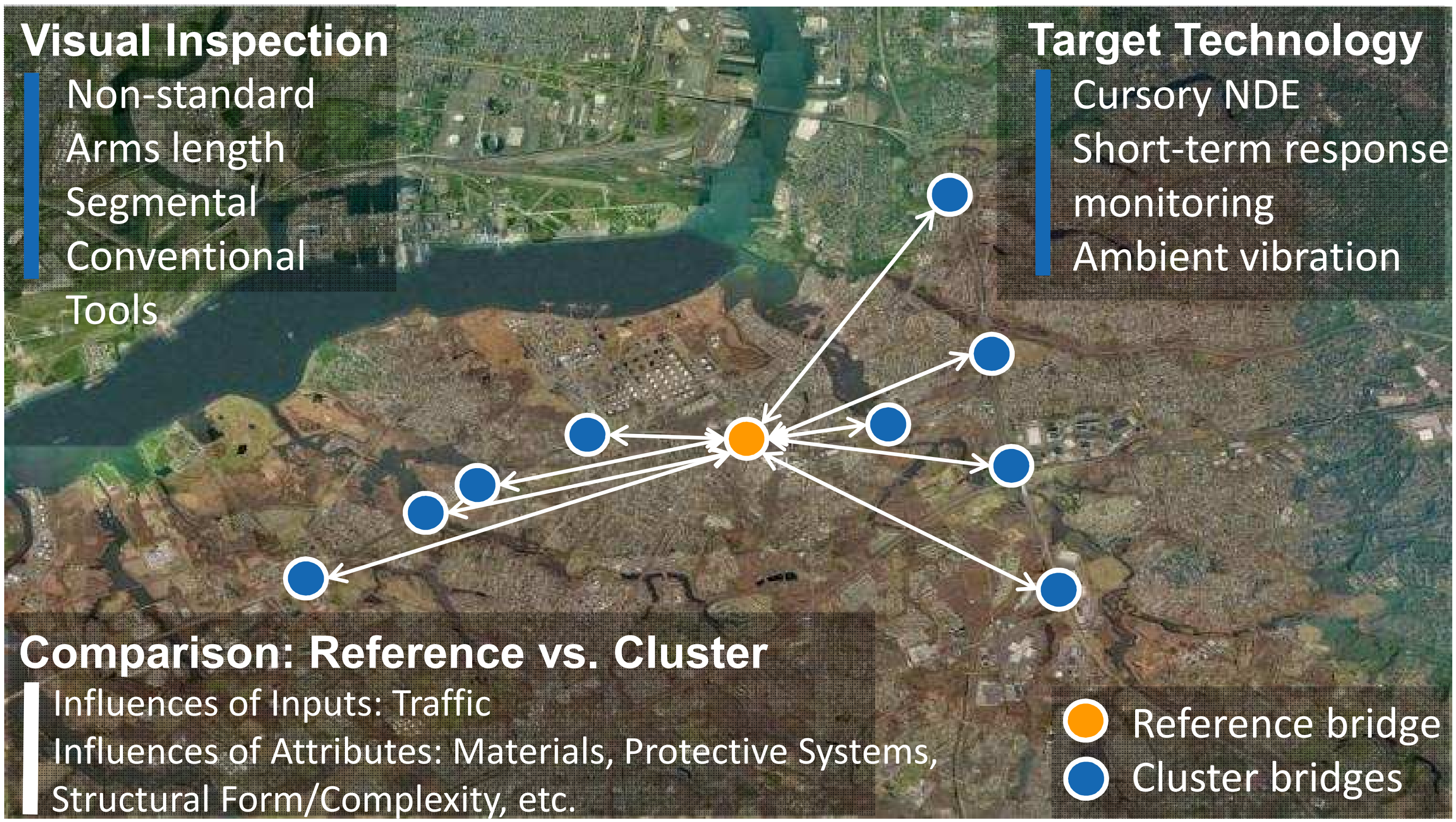
Approximate
Scale: 200 ft

Reference Bridge and Supporting Cluster



Approximate Scale: 30 mi

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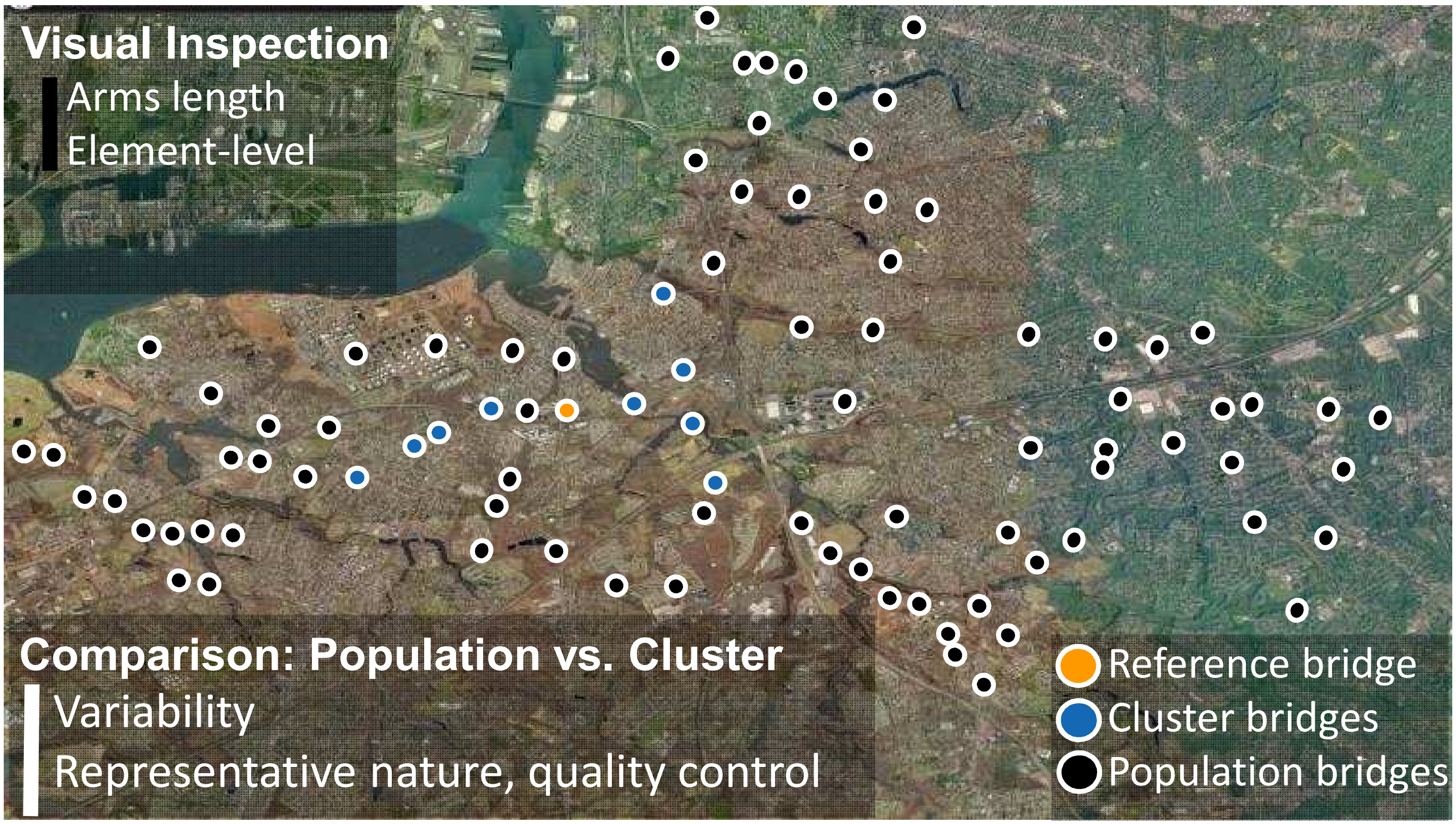
Reference Bridge, Cluster, and Supporting Population



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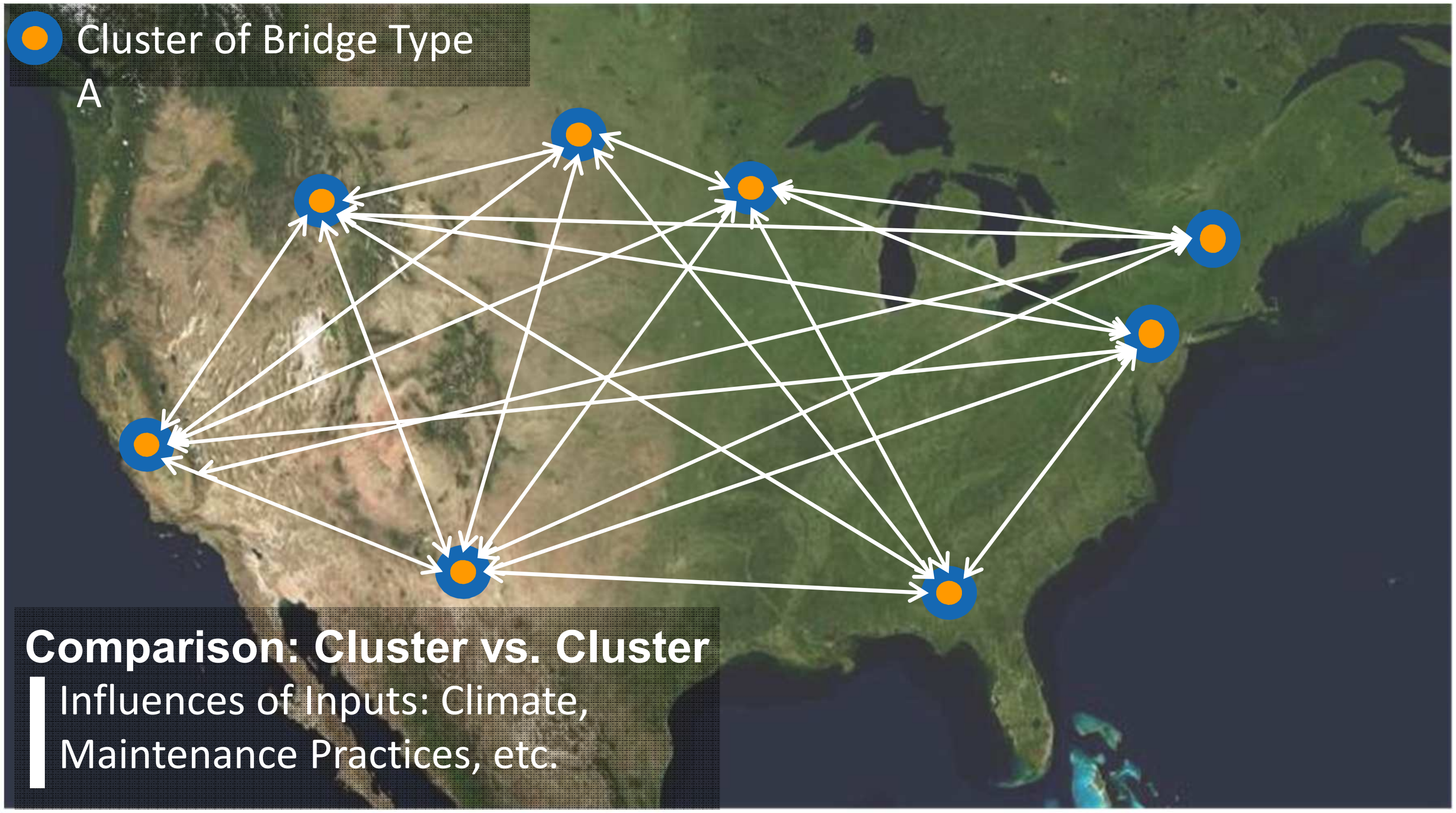
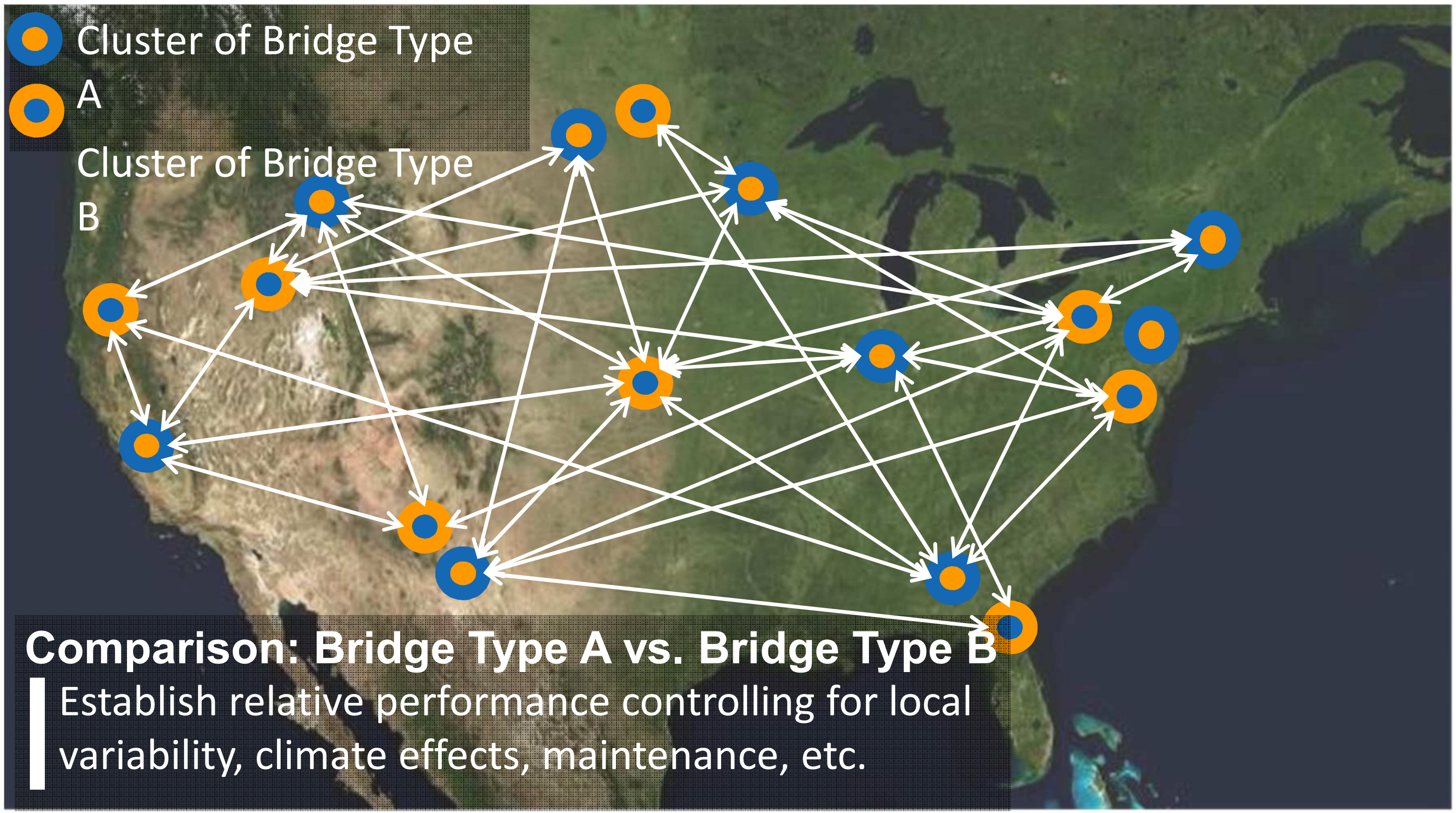
Approximate Scale: 150 mi

Multiple Clusters of Similar Bridges



Approximate Scale: 3000 mi

Multiple Clusters of Different Bridge Types



Comparison: Bridge Type A vs. Bridge Type B

- Establish relative performance controlling for local variability, climate effects, maintenance, etc.

Approximate Scale: 3000 mi

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